ARE OKLAHOMA CITY RESIDENTS OK?

A SOCIO-SPATIAL ANALYSIS OF PHYSICIANS AND SUPERMARKETS

VIA ACCESSIBIILTY AND AFFORDABILITY

By

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Are Oklahoma City residents OK? There are myriad ways to answer this question. However, some alarming statistics relating to health for Oklahoma residents indicate the answer is no[1] as the state ranks poorly for many health indicators. For example, Oklahoma is second in heart disease deaths, has high rates of strokes and deaths from diabetes, and has a higher infant mortality rate than the rest of the nation. Additionally, the state is the fifth least physically active. Unsurprisingly, the state has high numbers of residents who are overweight or obese, putting it in the top ten for obesity.

These statistics paint an unhealthy picture for residents in Oklahoma. However, these are aggregate state statistics that could be masking local variations across the state. Rather than analyzing the entire state, this research examines potential factors leading to poor health at the neighborhood scale within the state capital and its surrounding areas. The Metropolitan Statistical Area (MSA) of Oklahoma City includes the city and surrounding communities and counties. The MSA has just over 1.3 million people and is made up of seven counties. Each of these counties has a grade of D or F with regard to fruit and vegetable consumption, deaths due to heart disease, stroke, chronic lower respiratory disease, and diabetes. County governments are now trying to improve quality

[1] Oklahoma State Department of Health. 2008. State of the State's Health Report. Last accessed on 7 June 2011. www.ok.gov/health/pub/boh/state/

of life for residents by encouraging people to increase physical activity and eating more nutritiously[1]. Additionally, improving access to healthcare as well as early screening and prevention for children and adults are important goals for the counties of the MSA.

These statistics highlight the importance of health for a community. Yet, improving health can be a challenge without understanding the underlying factors that contribute to poor health. Therefore, it is important to understand where the underserved population lives before proposing solutions to health inequalities. For example, lower income residents are at higher risk for poor health, including higher rates of obesity, heart disease, chronic lower respiratory disease, and strokes. Additionally, low income residents have limited retail opportunities with potentially higher prices. While mechanisms linking neighborhood environment to individual health are not well understood, three potential mechanisms have been suggested in the literature: physician access, healthy food access, and healthy food availability and affordability.

These three mechanisms will be evaluated in this study through three separate but related projects. Rather than writing a traditional monograph dissertation, three articles will highlight potential problems for Oklahoma City residents. The three articles are based on literature examining why there are inequalities in health. Geographic variations in health inequalities are present among countries as well as within them. These variations have increased despite medical advancements. Although there is strong evidence linking individual health to who you are, there is also evidence linking individual health to where you live[2]. Research focusing on a larger area, such as the

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[2] Boyle, P., S. Curtis, E. Graham and E. oore. 2004. *The Geography of Health Inequalities in the Developed World: Views from Britain and North America*. Burlington, VT: Ashgate.

county level, can obscure localized variations and homogenize relatively dissimilar subunits. Research that focuses on a finer scale, such as Census tracts, reveals the way that health and behavior are affected by social and physical surroundings. Because other differences in neighborhoods may emerge that influence health, such as poor housing, lack of access to doctors, and reduced transportation, a finer-scale analysis can reveal new priorities for policy makers. Solutions can then be targeted more efficiently by understanding how the neighborhood milieu influences health. New housing, additional bus routes, ride-share programs, and downtown doctor's offices could improve health levels and convenience for those residents living in poor-access neighborhoods. This research focuses on the neighborhood scale in one metropolitan area to uncover heterogeneity in individual health and neighborhood environments.

One of the first lines of defense for protecting individual health is the primary care physician. If physicians are scarce, many people will overlook their symptoms and avoid medical attention. In addition to having medical service nearby to monitor any changes in health, diet is also important for individual health. Diets high in fruits and vegetables lead to decreased health risks[3]. Thus, this research will discretely analyze these three areas. Chapter 2 examines access to healthcare, specifically primary care physicians and urgent care centers. Chapter 3 evaluates access to healthy food vis-à-vis the locations of supermarkets. Chapter 4 builds upon food accessibility research and analyzes food prices and food availability in supermarkets.

[3] Latham, J. and T. Moffat. 2007. Determinants of Variation in Food Cost and Availability in Two Socioeconomically Contrasting Neighborhoods of Hamilton, Ontario, Canada. *Health & Place* 13: 273-287.

Chapter 2 Overview

Previous research has suggested that lack of access to primary care physicians could be a cause of poor health. Different subgroups within the population have increased need for medical care. Where these subgroups live can increase demand for health services. Therefore, Chapter 2 of this study analyzes the access to physicians for Oklahoma City MSA residents. This research focuses on the neighborhood scale (represented by Census tract centroids) and creates an index of accessibility to primary care physician locations. This index can then be mapped to highlight areas that could be experiencing poor access to physicians. Additionally, this index is compared to socioeconomic variables to evaluate the accessibility for various disadvantaged groups. The methodology used in this chapter is the two-step floating catchment area (2SFCA) and the Enhanced 2SFCA (E2SFCA). This technique uses both physician locations and Census tract centroids to analyze the supply and demand for physicians. The results of the 2SFCA and E2SFCA are then analyzed with spatial autocorrelation techniques to determine if any groups have poor access to physicians. This chapter was sole authored.

Objectives of Chapter 2:

- Understand how accessibility to physicians varies throughout the Oklahoma City MSA
- Determine if any socioeconomically-disadvantaged groups experience poor accessibility via spatial autocorrelation measures
- Provide findings that could lead to an overall improvement in health via better access to physicians

Chapter 3 Overview

An additional mechanism linking neighborhood environment to individual health is access to food stores. As cities have expanded farther into suburban areas, emptying near the center has occurred. The resulting decrease in population density has been responsible for inner-city locations being less profitable for retailers, especially with regards to food stores. Previous research has found higher rates of preventable disease such as diabetes, obesity, and hypertension in residents without a supermarket in their neighborhood. Chapter 3 thus examines food accessibility to evaluate how these poor health statistics might have arisen, a particularly important consideration given the poor health statistics for Oklahoma and Oklahoma City cited earlier.

Two techniques measure access to supermarkets. The first is a descriptive technique that analyzes distance to the closest and second closest supermarket. The second is the cumulative spatial opportunities (CSO) index, which is more sophisticated in that it quantifies the supply of supermarkets within a given distance threshold of consumers. Spatial autocorrelation techniques are then used to identify groups with poor access to supermarkets. This chapter was co-authored with Jonathan C. Comer.

Objectives of Chapter 3:

- Understand how accessibility to supermarkets varies throughout the Oklahoma City MSA
- Determine if any socioeconomically-disadvantaged groups experience poor accessibility via spatial autocorrelation measures
- Provide findings that could lead to an overall improvement in health via better access to supermarkets and healthier foods

Chapter 4 Overview

The third mechanism addressed in this paper builds upon supermarket accessibility (Chapter 3) and examines financial accessibility to food for residents. Physical access is an important component of nutritious food, yet if that healthy food is unaffordable and/or unavailable, chances are that unhealthy foods will be purchased instead. Low-cost foods tend to have higher caloric value and are energy-dense, making them filling but with fewer nutritional benefits. These high calorie and energy-dense foods can contribute to increased rates of cancer, gallstones, osteoporosis, and obesity. Chapter 4 examines how financial accessibility and food availability varies for residents in the Oklahoma City MSA. A specific basket of goods was priced in supermarkets throughout the MSA to measure price differentiation between various locations as well as socioeconomic groups. Finding price variations can provide evidence that not all residents can obtain healthy, affordable food. This chapter was sole authored.

Objectives of Chapter 4:

- Understand how prices for a specific basket of goods and food availability varies throughout the MSA
- Determine if any socioeconomically-disadvantaged groups experience price discrimination via statistical tests
- Provide findings that could lead to an overall improvement in health via purchasing of healthier goods

Summary

This dissertation analyzes access to physicians and supermarkets as well as the affordability of the food available at supermarkets in an attempt to determine whether residents of Oklahoma City are indeed OK. Physician and supermarket locations are analyzed due to the overwhelmingly negative health statistics found within the state as well as the counties that make up the Oklahoma City MSA. Although the poor health statistics portray the state negatively, research identifying links between individual health and neighborhood environment can improve the overall health of all Oklahomans.

Overall Objectives of the Dissertation:

- Understand the MSA’s accessibility to two key components to maintaining good health, physicians and supermarkets
- Correlate the accessibility indices and affordability results to socioeconomic data to identify specific groups that experience poor access or higher prices
- Provide city leaders and health officials with this information to address these findings and improve the health of residents living in the Oklahoma City MSA

CHAPTER II

MEASURING PHYSICIAN ACCESSIBILITY IN OKLAHOMA CITY

Abstract

This study evaluates physician access for residents located within the Oklahoma City, Oklahoma Metropolitan Statistical Area (MSA). The purpose is to identify areas within the MSA with limited access to physicians and determine if these residential areas of poor access correspond with disadvantaged socioeconomic groups. These "physician gaps" are identified by using a two-step floating catchment method in a geographic information system (GIS) using actual physician location and Census tract centroids. Three different techniques of the two-step floating catchment method are used to calculate an index of potential accessibility and correlate these physician gaps to concentrations of historically-disadvantaged groups. However, spatial autocorrelation occurs with the accessibility indices and appropriate techniques are used to address this problem. Bivariate correlation matrices are analyzed along with socioeconomic data from the Census Bureau relating to age, education, poverty, and race characteristics. For the Oklahoma City metropolitan area, physician gaps occur in the far southwest and eastern fringe of the MSA. Suburban locations tend to have less access than the central city due to the concentrated locations of healthcare facilities in Oklahoma City. These results reveal that inner-city residents have the best access to healthcare facilities across the MSA while rural residents have the worst access.

Introduction

A region's health is determined by a wide variety of factors, including both accessibility to services and the prevailing socioeconomic conditions. Studies of regional health have become more common over the past decade, especially with regards to the impact of residential location and health status. The concept of accessibility comprises not just locations of services and patients, but also the socioeconomic characteristics of patients, their needs, and perceptions (Andersen 1995). Therefore, understanding residential access to health services can allow for the promotion of better health and predict health service use (Yamashita and Kunkel 2010). Once locational and socioeconomic traits have been identified, solutions could be sought that reduce these geographical variations based on a better understanding of how the neighborhood milieu influences health.

Access to health services may not be the only factor influencing health in a neighborhood. The mechanisms linking neighborhood environment to individual health are not well understood, but some that have been introduced relate to accessibility to health care services and their availability (Gatrell 2002). Other factors may emerge that influence health, such as poor housing, cultural traits, and limited transportation. New housing, more bus routes, and additional ride-share programs could help improve the health of residents living in poor-access neighborhoods.

In addition, population subgroups have varying needs for healthcare. The elderly have more demand for services, minority populations have more barriers to utilization, including language issues and a possible lack of awareness of healthcare services, and lower income groups are unable to afford preventive care (Field 2000). Each of these subgroups has different demands for services and therefore the need of healthcare facilities fluctuates across the metropolitan area. In order to understand where and why these differing demands occur, a comprehensive supply of services available to the population is needed along with a better understanding of population needs.

Research that focuses at the neighborhood level reveals the way that health could be affected by social issues as well as poor access. Rather than generalizing country- or state-wide health, this study analyzes Census tracts as proxies for neighborhoods in one metropolitan area in support of an investigation of heterogeneity in physician access. This research addresses the impact of distance from a healthcare facility and its relationship to factors such as age, education, ethnicity, race, and poverty.

Background

Healthcare Access

Healthy People 2010 is a national agenda designed to identify problems affecting health in the United States and to establish the necessary protocols to reduce problems of poor health (Department of Health and Human Services (DHHS) 2010). One issue closely tied to poor health is inadequate access to physicians. For this paper, physicians who practice family medicine, internal medicine, and pediatrics are considered because these doctors most often represent the initial meeting for patients in need. Primary care physicians have predominantly been the first line of defense when combating health issues (Lee 1995).

However, having access to a healthcare facility does not assure utilization. Healthcare accessibility involves a wide variety of factors and issues, including distance to service providers, the ability to reach providers via transportation networks, strategies involving decision-making, and the socioeconomic status of individuals (Meade and Earickson 2000). Two main accessibility distinctions exist: potential and realized accessibility (Aday and Andersen 1974, Joseph and Bantock 1982). Potential accessibility analyzes the possible usage of a facility, whereas realized accessibility uses hospital discharge information or patient records (Joseph and Phillips 1984). Due to the unavailability of discharge data, this research focuses on potential accessibility.

Potential accessibility allows for a more thorough understanding of where facilities are located and how far residents must travel to use those services. Distance plays an important role when discussing healthcare utilization. Increased travel time, cost of travel, and ambulance services can impact travel to see a physician as well as an individual’s ability to combat diseases (Wang et al. 2008, Yamashita and Kunkel 2010). The timing of diagnosis for any type of disease affects survival rate and treatment options. During heart attacks, the closer a hospital facility and the quicker that admittance can occur, the higher the likelihood of survival (Hare and Barcus 2007, Yamashita and Kunkel 2010).

In the Chicago metropolitan area, Wang et al. (2008) found that poor access to primary care physicians was more strongly associated with late diagnosis of breast cancer than with poor access to mammography screening locations. They also revealed that minorities and low-income groups have a higher risk of being diagnosed with late-stage breast cancer (Wang et al. 2008). Additionally, Luo and Wang (2003) found that there was poor accessibility in rural areas as well as those areas with high concentrations of minorities and low-income residents in Illinois. Residents who have lower levels of education are at a higher risk of mortality from diseases such as diabetes, cancer, and heart disease (Commonwealth Fund Commission 2008).

Neighborhoods have characteristics that influence health in a variety of ways. Table 1 presents some of these traits, in terms of three environments: economic, social, and physical. The economic environment consists of amenities available in the neighborhood such as banks, grocery stores, healthcare facilities, and transportation options. The social environment includes job opportunities, income levels, racial makeup, and neighborhood unity. The physical environment also affects health by providing clean water, good housing, quality school buildings, and recreational activities (Bigby 2007, Bell and Lee 2011). Although an analysis of these environments is beyond the scope of this article, the social and economic environment will be evaluated by examining physician access, which is an economic aspect along with multiple factors that are present in the social environment.

Socioeconomic factors such as age, race, income, and gender influence a person's access to physicians (Joseph and Bantock 1982, Meade and Earickson 2000, Gatrell 2002, Boyle et al. 2004, Eibner and Sturm 2006). Studies have shown that women, low-income residents, and minorities have the least access to healthcare facilities (Gatrell 1997, Field 2000, Cromley and McLafferty 2002). Access is also influenced by distances to healthcare services. Considerable distances must be covered to find specialists when dealing with rare or serious health problems, whereas minor problems can be treated at a local healthcare facility. However, knowing where clinics are located and their distances are related to socioeconomic factors and individual choices (Nickerson and Hochstrasser 1970). An individual has a variety of choices, including avoiding treatment altogether, traveling to a distant facility, or utilizing another type of care such as in-home treatments. Therefore, accessibility is best understood by incorporating locations of healthcare facilities as well as residential locations for health services (Hare and Barcus 2007).

Table 2.1: Neighborhood Health Impact Factors

Economic Environment	
Healthcare Services	Grocery Stores
Banks	Restaurants
Jobs	Transit Friendly
Social Environment	
Cohesive Neighborhood	Income
Job Opportunities	Segregation
Violence	Cultural Institutions
Physical Environment	
Clean Water and Air	Quality Housing
Sidewalk Conditions	Parks and Recreation Space
Condition of School Buildings	Access to Roads and Transit

Adapted from Bell and Lee (2011)

Spatial and Aspatial Factors

Access to healthcare facilities is influenced by spatial and nonspatial factors. Spatial factors consist of the locations of health care providers and consumers. Nonspatial factors are concerned with the traits of consumers, including social, economic, and demographic variables. These include age, education, ethnicity, and income (Luo 2004, Wang et al. 2008). Access to healthcare facilities has been studied using a variety of techniques. Most approaches to access apply distances to and from a facility using either travel times or straight-line distances (Joseph and Phillips 1984). There are five common measures of accessibility: “the distance to the closest service; the number of services with *n* meters, miles, or minutes; the mean distance to all services; the mean distance to *n* closest services; and the gravity model" (Apparicio et al. 2008, 10). Other analyses have used either straight-line or travel-time distance from population centroids to physicians (Joseph and Bantock 1982, Guy 1986, Field 2000, Prentice 2006, Hare and Barcus 2007, Yamashita and Kunkel 2010). Rather than finding one measure that works the best, Apparicio et al. (2008) found that it was the scale that was most important when it came to minimizing errors in the data, that is, the larger the aggregation method the more chance of errors. Census tracts, block groups, or blocks yielded the lowest number of errors (Apparicio et al. 2008).

The increased use of geographical information systems (GIS) and availability of digital data has made it easier to compute measures of accessibility on a variety of scales (Cromley and McLafferty 2002, Luo and Wang 2003). In Kentucky, Hare and Barcus (2007) used fifteen minute travel time bands to understand hospital utilization rates and heart disease. The best accessibility occurred in the cities and the worst access existed for rural areas of Kentucky. In addition, the residents who had to travel the farthest for care were the most socially and economically disadvantaged (Hare and Barcus 2007). Using straight-line distance for Ohio counties, Yamashita and Kunkel (2010) evaluated heart disease mortality and access to hospitals. Their findings demonstrated that socioeconomically-disadvantaged groups have higher rates of mortality and that rural residents in Ohio had to travel the farthest for hospital access.

Two-Step Floating Catchment Method

The gravity model has also been used to evaluate accessibility (Joseph and Bantock 1982). This method consists of using the number of physicians divided by distance. However, the best way to measure spatial accessibility to healthcare is to combine two mechanisms: distance and demand versus supply (Yang, Goerge and Mullner 2006). The gravity model only incorporates distance with supply. Therefore, an expansion of the gravity model that accounts for demand is needed. This can be found in the two-step floating catchment area method (2SFCA) (Luo and Wang 2003). This technique merges both spatial and nonspatial factors in an accessibility measure (Luo and Wang 2003, Luo 2004, Wang and Luo 2005, Wang et al. 2008, Luo and Qi 2009, McGrail and Humphreys 2009a). Rather than relying solely on the physician location or the location of the consumer, the 2SFCA measures a distance around *both* locations and evaluates the physician-to-population ratio. This is important because analyzing physician (supply) accessibility would be measuring only one aspect of healthcare availability. A more complete understanding of accessible facilities is gained by analyzing how both supply and demand in different areas affect access to health care and, in turn, neighborhood health.

The 2SFCA allows for both physician supply and population demand to be examined within some distance requirement. The threshold travel time between population and healthcare facilities is defined as thirty minutes, a standard used by the U.S. Department of Health and Human Services for defining service areas (Department of Health and Human Services (DHHS) 2009). The 2SFCA has been used to study physician accessibility in previous healthcare research (Luo and Wang 2003, Luo 2004, Wang and Luo 2005, Wang et al. 2008, Luo and Qi 2009, McGrail and Humphreys 2009a). Many previous studies have examined Chicago and the state of Illinois. First used in Chicago, the 2SFCA demonstrated that the worst access to physicians existed on the city's south side and in rural areas (Luo and Wang 2003). Additional research in Chicago analyzed breast cancer diagnosis and access to facilities (Wang et al. 2008) finding that residents living in disadvantaged areas have higher risks of a late-stage diagnosis. However, no significant results were found with diagnosis and travel time to mammography centers (Wang et al. 2008).

This 2SFCA method is not without its limitations. Although it uses both physician locations and residential locations, it operates with an assumption that everyone living in the distance threshold has access. The method does not account for distance decay effects, (i.e. there is no differentiation between physician locations that are close to home and those that are twenty minutes away). As long as there is a healthcare facility location within the distance threshold, the residents have access (Wang and Luo 2005). Additionally, any physician or resident positioned outside of the distance threshold is considered inaccessible and residents are assumed to have no access (Luo and Qi 2009). Rural residents in general travel farther in order to obtain healthcare services, but the 2SFCA does not allow for any differentiation of distance based on location. For areas that have larger populations of elderly or young children, the medical needs are increased so the ratios and travel times need to be adjusted. This is another limitation of the 2SFCA (Luo and Qi 2009). Access measures that take into consideration more than just one travel time will provide a better measurement of equitable accessibility.

In Australia, 2SFCA was used to examine physician location using two different catchment sizes, a fifteen minute travel time and a sixty minute travel time. McGrail and Humphreys (2009b) found the ability to use different sized catchment areas, depending upon the location, provided a more realistic picture of accessibility than just using a one-size fits all approach. They found that the 2SFCA method has the ability to analyze access at a smaller spatial resolution and therefore aid policymakers in improving the healthcare accessibility for residents living in rural Australia.

In response to the lack of distance decay, Luo and Qi (2009) developed the enhanced two-step floating catchment area method (E2SFCA). The thirty-minute catchment area is still used, but it is subdivided into three zones based on ten minute intervals and differential weights are applied to each zone. This permits adjustments to the weights for the different time intervals. For less distance decay, weights are reduced at a smaller pace. Each of the weights can be adjusted depending on the type of area under investigation to account for topographic, transportation, or other travel-based differences (Luo and Qi 2009). A limitation of using the travel zones and distance decay is the issue of identifying the correct number of zones. This problem is addressed by using a Gaussian function which continuously adjusts accessibility without breaking the catchment areas into zones (Dai 2010).

Additionally, 2SFCA provides no alternative measures for residents with mobility problems. People with no vehicular transportation or with a disability would have a much smaller distance threshold due to their inability to travel long distances. By understanding the behavioral factors of the residents, the catchment areas could be modified for residents having limited access to transportation, such as residents with disabilities and who are otherwise socially disadvantaged.

To account for these limitations, this study uses two methods to evaluate accessibility to healthcare facilities. The 2SFCA is used as well as the E2SFCA with weights for distance decay. One problem with each of these methods is that facilities may be located just outside the study area, which would skew accessibility. This was accounted for by including facilities located just outside of the periphery. Those facilities that fell within the fifteen minute buffer were incorporated into the thirty-minute catchment areas where appropriate (Luo and Wang 2003). Accessibility results along the periphery of the study area must be interpreted with caution, as the residents may use healthcare facilities outside the study area and outside the fifteen-minute buffer as well. Additionally, the E2SFCA with weights for distance decay is calculated in order to gain a better understanding of the accessibility to healthcare facilities and to compare this method to the original 2SFCA.

One of the benefits of using the 2SFCA is its ease of interpretation (Yang, Goerge and Mullner 2006). The method employs a physician-to-population ratio that has been used for healthcare shortage areas within the Department of Health and Human Services (DHHS) (Luo 2004). The 2SFCA and E2SFCA provide an accessibility index that can be mapped to highlight areas having good access and poor access to healthcare facilities in order to determine if any residents are living in a physician gap. The spatial accessibility of healthcare facilities will identify residents who have inadequate access to medical services and allow government officials and policy makers to better allocate funds to enhance access to healthcare for these residents (Luo and Qi 2009). Better accessibility corresponds with a higher accessibility index and can be interpreted as more physicians per population (Wang and Luo 2005).

Once these indices have been created, correlating the socioeconomic variables with the indices is the next step in order to determine if any positive or negative correlations are present. However, neighborhood data has a tendency to exhibit spatial autocorrelation, in which observations are not independent of one another. This is an important issue to understand because most statistical models assume independent observations. In this context, traditional correlation and regression analyses must be undertaken with care, or alternatively other methods can be used to account for and measure spatial autocorrelation to uncover relationships that exist between the accessibility indices and the socioeconomic indicators.

Spatial Autocorrelation

Methods that account for spatial autocorrelation have been developed by geographers, statisticians, and many others. The issue that arises from autocorrelated data, especially in the context of correlation and regression, is that the standard errors are underestimated and hence the methods overestimate the significance of relationships found. These lower standard errors occur because the statistic might be measuring dependence from an unknown variable and not because the two variables are actually related (Haining 1990). Yet, an objective of statistical analysis is to find out if two variables influence one another or not, so accounting for autocorrelation must be addressed. A possible way to account for autocorrelation is to estimate the effective sample size by eliminating the effect from the data (Haining 1990). However, estimating the effective sample size is time consuming and difficult. Instead, other methods are used that measure autocorrelation and use that information to understand how neighbors influence physician access and socioeconomic characteristics.

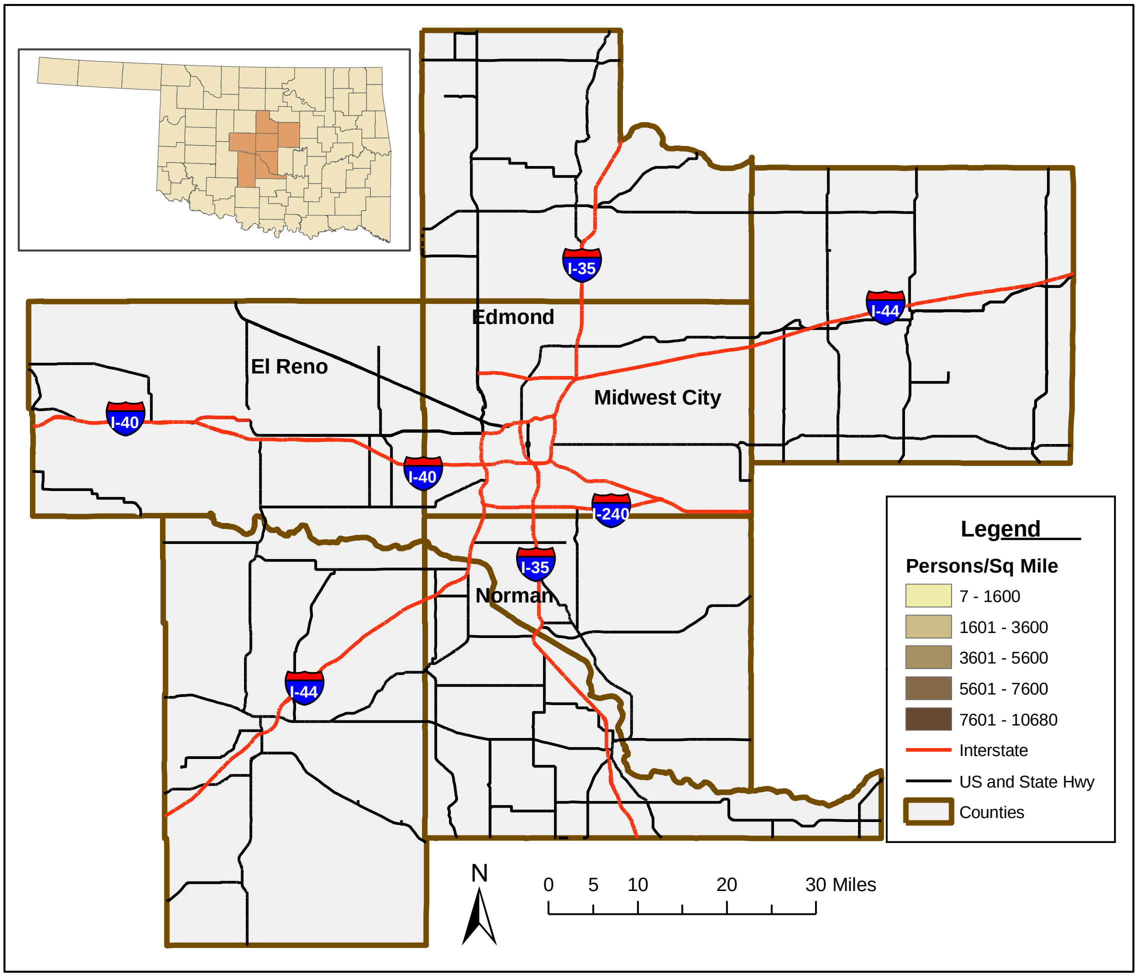
The first step is to identify any spatial autocorrelation present in the data. This is accomplished by using a global statistic, which produces a value that is similar to a correlation coefficient. The most common global measure is Moran's I. Like Pearson's r, positive autocorrelation occurs when I approaches one and negative autocorrelation occurs when I approach negative one (Moran 1948, 1950).

Global statistics provide an understanding if autocorrelation is present but provide a more generalized measure. Pockets of autocorrelation may exist at a more local level and methods have been created to find these pockets, including Moran's I_i (Anselin 1995) and the family of G_i statistics (Getis and Ord 1992), among others. These local statistics identify hot spots of related observations by calculating statistics based on Census tracts. *GeoDa* is used to calculate the global and local statistics as well as produce maps and graphs that can be used for further analysis (Anselin, Syabri and Kho 2010).

Study Area

Oklahoma City is chosen for study (Figure 2.1) due to poor rankings in terms of residential health status. In 2010, Oklahoma was ranked 46th in the nation for overall health, with lack of access to doctors contributing to this poor health ranking (Muchmore 2010). Understanding where health inequalities take place and determining what can be the cause is vital to improving the health of the residents of Oklahoma City.

Figure 2.1: Oklahoma City MSA with Population Density Mapped



The MSA has just over 1.3 million people, contains the state's largest city, and is made up of seven counties in central Oklahoma (U.S. Census Bureau 2010). It was the fastest growing city in Oklahoma between the 2000 and 2010 Censuses and since 2000 has experienced an increasing number of minorities, especially Hispanics (U.S. Census Bureau 2010). The MSA contains a large metropolitan area and suburban communities as well as rural areas with very low population densities.

Oklahoma City has few people living in the inner city. Housing construction in the central city has increased, but few people live downtown. Additionally, there are low population densities on the rural fringe of the MSA. The majority of the central business district contains office buildings, conference centers, arenas, and hotels. However, there are a number of medical facilities in the central business district with hospitals, medical office buildings, and physician offices. Therefore, unlike other research that has found inner-city residents with poor access to physicians, Oklahoma City's rural residents will likely have poorer access than the urban residents.

Only one previous study has analyzed physician access in Oklahoma City. Knox (1982) analyzed seventeen different facilities, such as banks, dentists, golf courses, general medical practitioners, and department stores. He found that few residents had good access to all facilities. Residents living in the inner city had good access to employment opportunities but very low access to hospitals, libraries, and community centers. Residents living in suburban areas, in contrast, had good access to golf courses and hospitals, but not employment opportunities (Knox 1982).

Other research in Oklahoma City has examined accessibility to parks and found tracts with better access corresponded to Hispanic and low-income population clusters, whereas heavily African-American and Asian tracts had less access to parks (Comer and Skraastad-Jurney 2008). Thus, this study will build upon previous work in Oklahoma to determine if the same areas have poor health access or if these areas have improved.

Data

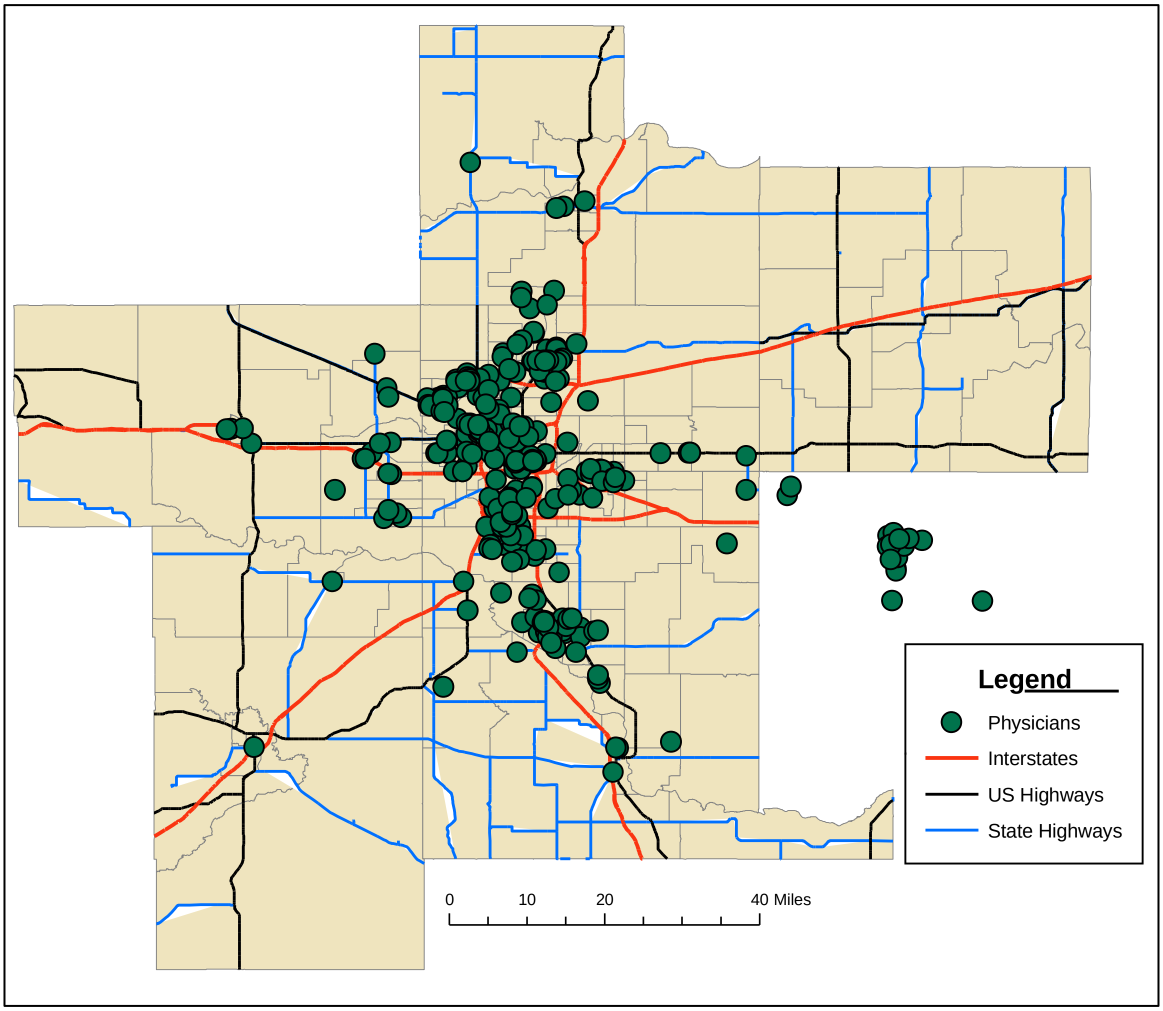
Location Data

This study uses tract centroids, physician locations, and transportation network features in order to measure distance between the MSA's population and physicians. The use of Census tracts serves as a proxy for neighborhoods and is therefore chosen as the spatial unit of analysis. Census tracts tend to represent neighborhoods with similar socioeconomic characteristics (Luo and Qi 2009).

For the purposes of this study, primary care physicians, general practitioners, general internists, and pediatricians are all included. Rather than using data from the American Medical Association containing zip codes for physicians (Luo and Wang 2003, Wang et al. 2008, Luo and Qi 2009), this study uses actual physician locations based on the telephone directory (Directory 2009) and verified with site analysis. This represents an improvement on past studies of physician accessibility by using the actual locations of physician offices rather than zip codes that often correspond to physicians' residences.

There are 884 physicians located in the MSA with the majority found along the central corridor (Figure 2.2). The physician locations and population density (see Figure 2.1) provide a strong visual correlation. Suburban and rural areas have lower accessibility due to larger populations and smaller numbers of physicians. The lack of physicians on the eastern side of the MSA and its low population density highlight this area as a potential physician gap. Additionally, the southwest area of the MSA has a physician, but its population is too large for just this one physician, which could represent a physician gap as well.

Figure 2.2: Physician Locations



The transportation network was obtained from the Oklahoma Center for Geospatial Information (OCGI) (2010) and was used to identify catchment zones based on travel time. This database consists of interstates, state and U.S. highways, and secondary roads. A network database was then constructed using the Network Analyst extension in ArcGIS 9.3 (Environmental Services Research Institute (ESRI) 2009). The closest facility tool was used to identify the catchments around the physicians and tract centroids.

Socioeconomic Data

Neighborhood-level variables (Census tracts) from the 5-year American Community Survey were used to evaluate the neighborhood differences of healthcare facility access against a wide variety of variables. These data are the most up-to-date that include population and housing characteristics. The American Community Survey is a population estimate based on a sample of approximately two million people. The data were collected from January 1, 2005 to December 31, 2009 (U.S. Census Bureau 2009). Census tracts tend to represent neighborhoods with similar socioeconomic data and demographic characteristics (Luo and Qi 2009) and so this study uses tracts as a substitute for neighborhoods. While the Oklahoma City MSA encompasses 334 total tracts, one downtown tract has no population and is excluded, leaving 333 observations.

Based on previous literature regarding populations that are most at risk for poor health, a variety of socioeconomic and demographic traits are examined. Minority populations have been found to have poorer access in previous metropolitan studies. In order to determine if similar problems exist in Oklahoma City, the percentages of African-Americans, American Indians, and Hispanics are included in this study. Additionally, socioeconomic factors such as income and educational attainment have contributed to residential health disparities and are included by using the percentage of residents living in poverty and the percentage of residents who lack a high school diploma. A need for access to healthcare facilities increases throughout our lifespan and therefore the percentage of population aged sixty-five and older is analyzed. Transportation access can be vital when suffering an illness or disease, and so the percentage of persons without a personal vehicle is included.

Table 2.2 summarizes the ACS data used in this study and shows both the variables of interest and the larger populations from which they are drawn. For example, poverty is based on a subset of the total population for whom poverty is determined, not the entire population, as individuals living in group quarters (prisons, mental health facilities, etc.) are excluded from the computation. Similarly, educational attainment of a high school diploma is computed for only those residents age 25 and older, and car ownership is computed only for those persons age 16 and older.

Table 2.2: Variables with Table Number and Definition from ACS 5 Year Estimates

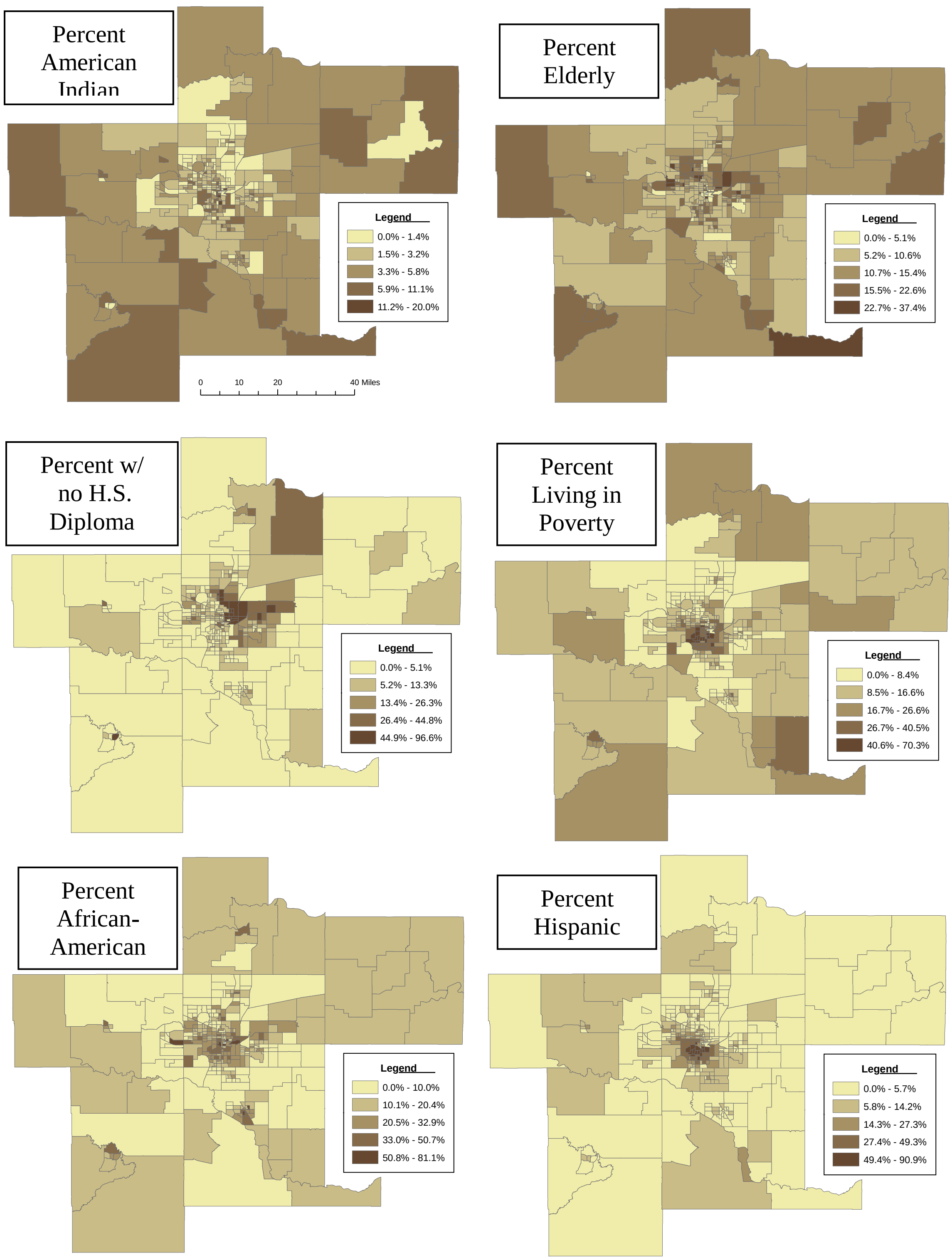
Variable of interest	**ACS table**
Percent African-American	B02001 – Race
Percent American Indian	B02001 – Race
Percent Hispanic	B03002 – Hispanic or Latino by Race
Percent with no diploma	B08141 – Sex by Age by Educational Attainment for the Population 25 Years and Older
Percent in poverty	B17001 – Poverty in the Past 12 Months by Sex by Age
Percent elderly	B01001 – Sex by Age
Percent with no vehicle	B08141 – Means of Transportation to Work by Vehicles Available for the Population 16 Years and Older

The Oklahoma City MSA is predominantly white, with African-Americans and Hispanics as the two largest minority groups at 9.9 and 9.5 percent, respectively. Although not mutually exclusive in Census tabulations, these two groups are mostly segregated into two distinct parts of the city, African-Americans being concentrated to the east of the downtown core near the state capital and Hispanics clustered southwest of the downtown area. The MSA is very large in area and vehicular use is the dominant form of transportation. The population of the MSA is 11.7 percent elderly, has 14.9 percent of its population living in poverty, 12.6 percent of its adult (age 25 and over) population lacks a high school diploma, and just 2.1 percent of persons age 16 and over do not own a vehicle. Though the state of Oklahoma has a strong American Indian presence, just 3.2 percent of the MSA population self-identifies as such.

Spatial patterns of these variables are illustrated in Figure 2.3. Each map is classified by natural breaks to highlight extremes within each variable/map. Therefore, the maps cannot be compared to each other directly for the purposes of identifying higher or lower percentages of the phenomena depicted based on shading. Also, a map of vehicle ownership is omitted. Just two percent of the MSA population lacks a vehicle overall, and in 85 percent of the tracts less than 5 percent of the population is without a vehicle, so there is very little spatial diversity in this variable.

Suburban locations experience the lowest percentages of poverty, while the rural fringe has the highest percentages of elderly populations. Residents without a high school diploma are concentrated just to the south of the center city as well as along the rural fringe. Minority populations are segregated into two main areas of the city. African-Americans are concentrated east of the inner city, near the state capital, whereas Hispanics are clustered just to the southwest of downtown. American Indians are located within rural areas rather than in the central city and there is a relatively small percentage of American Indians in the MSA with 20 percent as the highest percentage per tract. Due to the majority of physicians in the heart of Oklahoma City, minorities, those living in poverty, those with low educational attainment, and those without a vehicle will have the best access to physicians. Elderly residents and American Indians will have the poorest access to physicians due to higher percentages living in the rural areas.

Figure 2.3: Socioeconomic and Demographic Variables in the Oklahoma City MSA



Method

In order to measure accessibility of physician locations for the MSA population and distinguish areas of better or worse access, the 2SFCA method is used to account for both supply side (physician office locations) and demand side (population vis-à-vis Census tract centroids) location patterns. The 2SFCA is tied to the physician-to-population ratio and so is an easily-interpreted value (e.g., a value of 0.001 represents one doctor per thousand residents) with higher values indicating better access. Then, patterns of 2SFCA values are spatially correlated with socioeconomic indicators to determine if any historically-disadvantaged groups experience poor access and therefore may be at risk of a variety of poor health conditions as noted earlier in the Background section.

This technique is carried out using GIS through a series of buffers, joins, and summations. Using the "Closest Facility" option in the Network Analyst extension in ArcGIS 9.3, drive time buffers are created. In order to calculate the 2SFCA, the first step consists of calculating a thirty minute drive time buffer around the physicians. Physicians found within these buffers are summed. Next, the populations of the physician catchments are summed by including any tract centroid that is found within the buffer. The two pieces needed for the first step calculation are known (number of physicians and population) and the initial physician-to-population ratios are computed. For easier interpretation, the initial ratios are multiplied by 1,000. The initial ratios are then joined back to the physician shapefile for the next step. The second step consists of calculating a thirty minute drive time around the population centroids. Any physician found within this buffer captures the physician-to-population ratios and the ratios are summed together to compute the accessibility index to physicians at the neighborhood level.

Step 1 for the original 2SFCA:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_o\}} P_k}$$

Where:

P_k is the population of Census tract *k* whose centroid falls within the catchment (i.e. $d_{kj} \leq d_o$)
S_j is the number of physicians at physician location *j*, and
d_{kj} is the travel time between tract *k* and physician location *j*

Step 2:

$$A_i^F = \sum_{j \in \{d_{ij} \leq d_o\}} R_j = \sum_{j \in \{d_{ij} \leq d_o\}} \frac{S_j}{\sum_{j \in \{d_{ij} \leq d_o\}} P_k}$$

Where:

A_i^F represents the accessibility at Census tract centroid *i* based on the 2SFCA,
R_j is the physician-to-population ratio at physician location *j*, and
d_{ij} is the travel time between catchment area *i* and physician location *j*

One limitation of the 2SFCA mentioned earlier is that facilities located twenty minutes away have the same access as those only two minutes away. The second method in this paper is the enhanced two-step floating catchment area method (E2SFCA), which analyzes physicians and population in 10 minute increments and applies a distance decay function. For each physician and population centroid, travel times are computed for 0-10, 10-20 and 20-30 minutes (zones 1-3 respectively) (Luo and Qi 2009).

In order to calculate the E2SFCA, the first step consists of calculating a ten minute drive time buffer around physicians. Physicians found within these buffers are summed together. Next, the populations of the physician catchments are summed by including any tract centroid that is found within the buffer. This is repeated again for the twenty-minute drive time and again for the thirty-minute drive time. The two pieces needed for the first step calculation, number of physicians and population, are known and the initial physician-to-population ratios are computed. Again, after this initial ratio is completed, it is multiplied by 1,000 for easier interpretation. During this stage, review of the data is necessary in order to avoid double counting. That is, physicians and tracts that were found in the ten minute drive time might also have been counted in the twenty minute drive time, which would skew accessibility measures.

Each zone has a physician-to-population ratio that is summed together and joined back to the physician shapefile for the next step. The second step consists of calculating a ten minute drive time around the population centroids. Any physician found within this buffer includes the initial physician-to-population ratios and these ratios are summed together to compute the accessibility index to physicians within ten minutes. This is repeated again for the twenty-minute drive time and again for the thirty-minute drive time. The three travel time physician-to-population ratios are summed together at the tract level to reveal healthcare facility access at the neighborhood level.

Finally, a third approach in this study assigns differential weights to each travel time zone of the E2SFCA in order to apply a distance decay function. The main issue with using this type of method is deciding on the weights to apply and therefore two procedures of the E2SFCA are executed. In the first procedure of the enhanced model (E2SFCA-Slow), a slower rate of distance decay is used by multiplying 1.00, 0.68, and 0.22 to the initial physician-to-population ratios as well as to the final physician-to-population ratios for the three travel time zones, respectively. The second procedure (E2SFCA-Fast) uses a sharper rate for distance decay by incorporating 1.00, 0.42, and 0.09 as the weights for the three travel time zones, respectively. These weights are also applied to ratios computed at the buffers around the physician centroids as well as the ratios for the tract centroids.

Step 1 for incorporating distance decay into E2SFCA:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_r\}} P_k W_r}$$

$$= \frac{S_j}{\sum_{k\in\{d_{kj}\in D_1\}} P_k W_1 + \sum_{k\in\{d_{kj}\in D_2\}} P_k W_2 + \sum_{k\in\{d_{kj}\in D_3\}} P_k W_3}$$

Where

P_k is the population of Census tract *k* whose centroid falls within the catchment (i.e. $d_{kj} \leq d_r$)

S_j is the number of physicians at physician location *j*, and

D_r is the r^{th} travel time zone (r = 1-3)

W_r is the weights applied to the r^{th} travel time zone

Step 2 for incorporating distance decay into E2SFCA:

$$A_i^F = \sum_{j\in\{d_{ij}\in D_r\}} R_j W_r$$

$$= \sum_{j\in\{d_{ij}\in D_1\}} R_j W_1 + \sum_{j\in\{d_{ij}\in D_2\}} R_j W_2 + \sum_{j\in\{d_{ij}\in D_3\}} R_j W_3$$

Where

A_i^F represents the accessibility at Census tract centroid *i* based on the E2SFCA,

R_j is the physician-to-population ratio at physician location *j*, and

d_{ij} is the travel time between catchment area *i* and physician location *j*

W_r is the weights applied to the r^{th} travel time zone

To compare the three different methods of the two-step floating catchment areas mentioned above, Table 2.3 summarizes the main features of the three methods.

Table 2.3: Healthcare Facility Access Methods

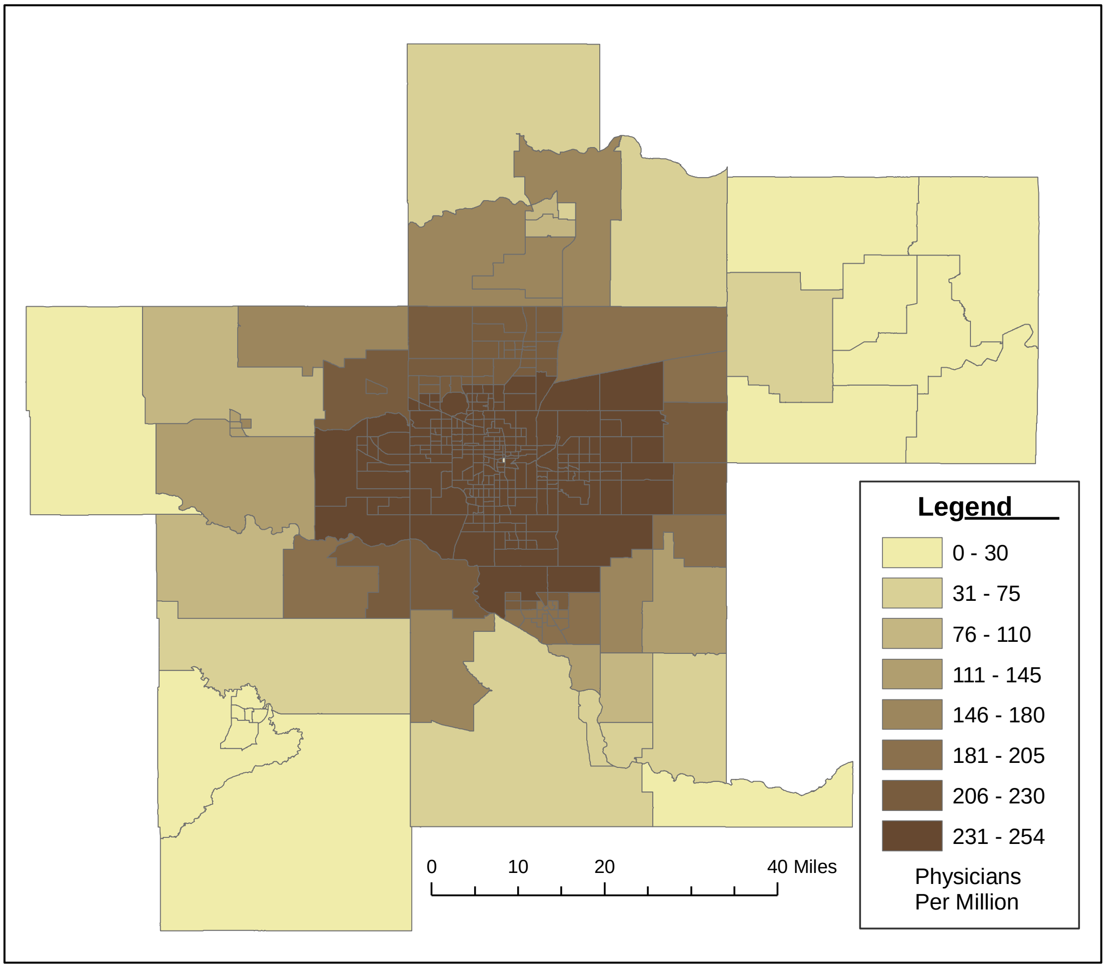
Procedure	Name	Description
1	2SFCA	One Thirty Minute Catchment Area (no distance decay)
2	E2SFCA_Slow	Three Travel Zones in Ten Minute Increments with 1.00, 0.68, and 0.22 distance decay weights
3	E2SFCA_Fast	Three Travel Zones in Ten Minute Increments with 1.00, 0.42, and 0.09 distance decay weights

Results

The result of using the original 2SFCA (Procedure 1 in Table 2.3) is shown in Figure 2.4. This highlights the central city as having the best access due to the clustering of healthcare facilities. There is a decrease in access away from the central city, with the outer fringe of the MSA having very poor access to healthcare facilities. This was an expected outcome due to the concentrated nature of the healthcare facilities (Figure 2.2).

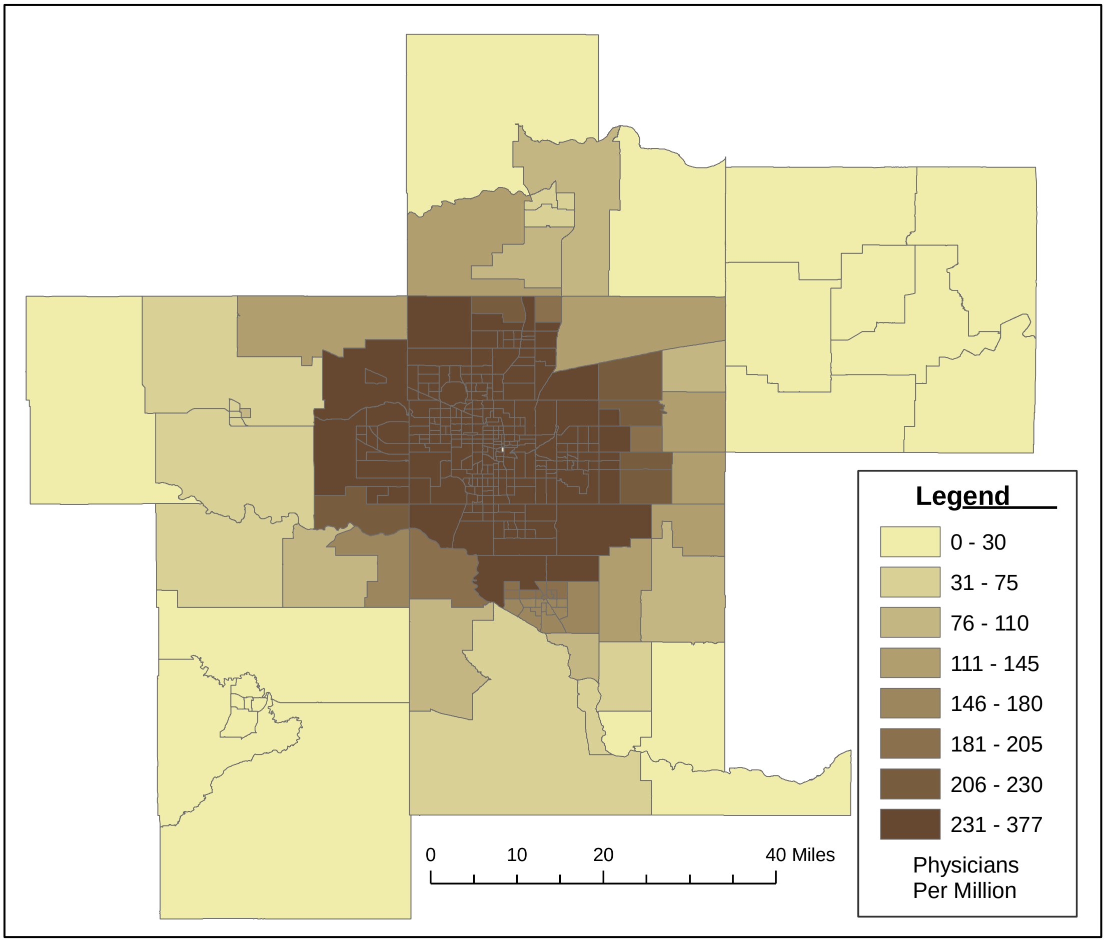
The accessibility result that the original 2SFCA produces is very similar to the pattern of healthcare facilities in Oklahoma City. Strong concentrations of healthcare facilities in the central part of the MSA correspond to high rates of accessibility from the 2SFCA. Those areas on the periphery of the MSA that have very few healthcare facilities, in turn, have very poor accessibility using the 2SFCA. There is a concentric pattern that follows the high accessibility in the center and gradually gives way to poor accessibility on the outer fringe. Unfortunately, the 2SFCA does not reveal any patterns beyond what could be discerned just by looking at the locations of healthcare facilities in the MSA.

Figure 2.4: Healthcare Facility Access using the 2SFCA



The E2SFCA_Slow (Figure 2.5) has a similar physician accessibility result as the one produced with the 2SFCA (Figure 2.4). Incorporating the distance decay function with weights, the E2SFCA_Slow uses a slower rate of decay with weights of 1.00, 0.68, and 0.22 for the three travel time zones, respectively. The central city still has good access, but those tracts on the suburban edge and metropolitan fringe have much lower access with this method. By using the three travel time zones a much more concentrated area of high access emerges in the central city with lower access around the periphery.

Figure 2.5: Healthcare Facility Access using the E2SFCA_Slow



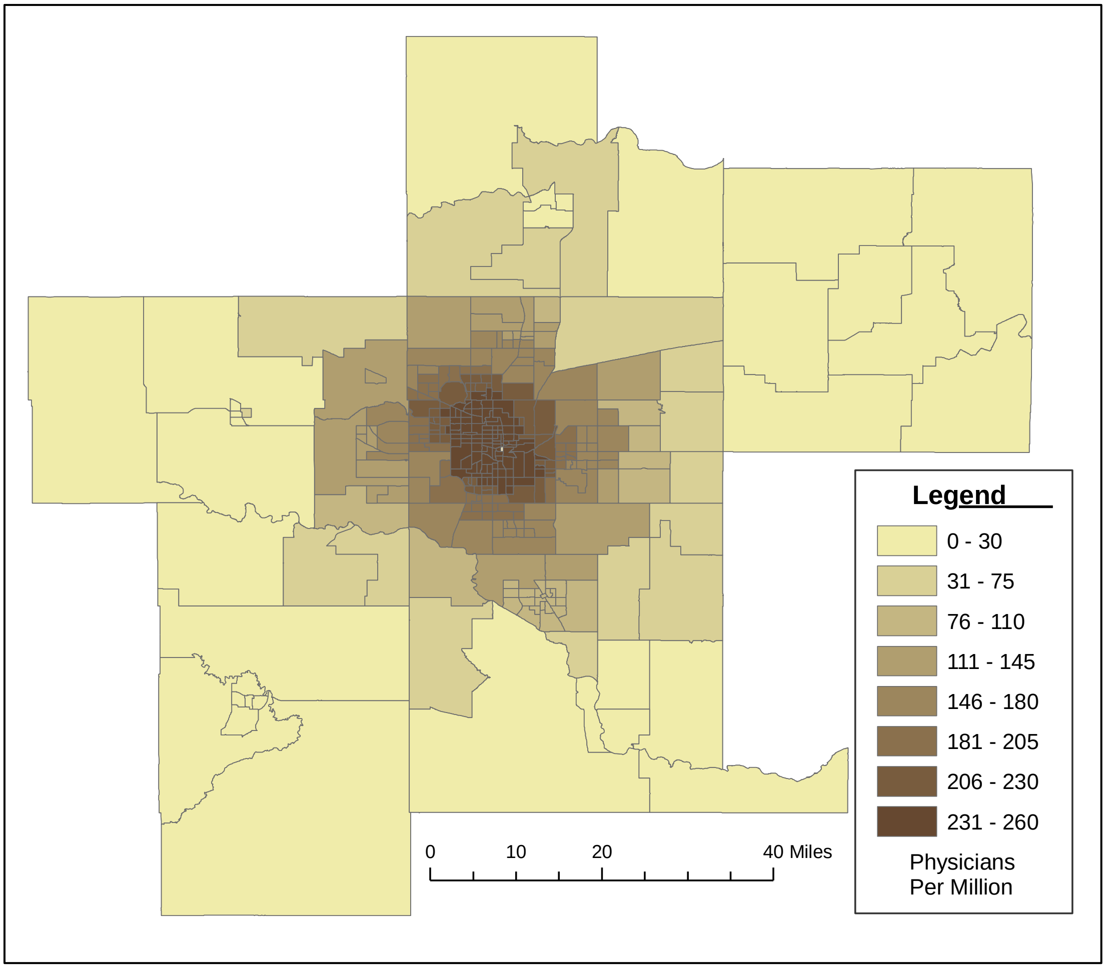
A comparison of Figures 2.4 and 2.5 show a similar accessibility pattern with regards to the areas of low accessibility, specifically the eastern and southwestern parts of the MSA. The E2SFCA_Slow results reveal greater accessibility detail than the 2SFCA, because the original method does not include any spatial variation in its catchment areas. For example, in the area around the inner city, the E2SFCA_Slow reveals a concentrated pattern of accessibility with higher values around the cluster of healthcare facilities (as shown in Figure 2.2) and lower values at its periphery, whereas the 2SFCA displays a more graduated effect from high accessibility from the center to the periphery with lower accessibility (Figure 2.4).

An additional benefit with the E2SFCA is that population characteristics of an area have more impact due to the three travel time zones. For example, just to the south of the central city, there is a cluster of healthcare facilities that has smaller numbers of physicians, yet the area is a highly populated suburb which in turn yields lower accessibility values. This is an issue where demand outweighs supply. The same can be said just to the north of the central city, yet the healthcare facilities have a higher number of doctors and lower population, which yields better accessibility values. The opposite issue occurs in that supply and demand are closer to equilibrium. These subtleties are harder for the 2SFCA to detect.

The result of E2SFCA_Fast is that higher accessibility is much more concentrated than the result from the 2SFCA. The original 2SFCA reveals high accessibility for the majority of residents and only those on the very outer fringe have poor accessibility. Using the E2SFCA_Fast shows only a handful of areas with high accessibility and much poorer access for those outside the city and on the fringe. Figure 2.6 shows the third E2SFCA with faster rates of distance decay with 1.00, 0.42, and 0.09 for the three travel time zones, respectively.

The two versions of E2SFCA are quite similar, but still show differences with regard to the central corridor of the MSA. The E2SFCA_Slow (Figure 2.5) reveals a subtle decrease of accessibility, yet this could be a factor regarding the range of values. These differences in values of the accessibility index are a result of the different weights applied during the two stages. The range of accessibility values for the E2SFCA_Fast is smaller than that for the E2SFCA_Slow, yet the overall pattern is the same. Both reveal the central corridor tracts have the highest number of doctors close at hand, whereas the

Figure 2.6: Healthcare Facility Access using the E2SFCA_Fast



residents located along the periphery must travel farther to see a physician. The E2SFCA further highlights poor access for those residents who live outside the central city, especially those who live on the southwest and eastern areas of the Oklahoma City MSA.

Comparing the E2SFCA_Fast with the 2SFCA reveals a different pattern of accessibility for residents of the MSA. Figure 2.4 highlights the majority of the MSA with high accessibility, yet using a sharper rate of distance decay and three travel time zones (Figure 2.6) reveals only a very small number of tracts with high accessibility. The periphery has poor accessibility, yet the northern, western, and southern suburban areas have only moderate accessibility using sharp distance decay. Again, this is due to the lower numbers of physicians located in these areas that have large populations. Comparing the 2SFCA against the E2SFCA_Slow and E2SFCA_Fast highlights the level of detail that arises from using the separate travel time zones rather than one single catchment size. Ultimately, however, these differences are relatively fine; Pearson's *r* correlations between each pair methods listed in Table 2.3 result in values of 0.982 (Procedures 2 and 3), 0.911 (Procedures 1 and 2), and 0.833 (Procedures 1 and 3), so the overall accessibility as measured by any of the three methods is quite consistent.

Two main areas of interest are revealed in each of the accessibility maps: the southwest part of the MSA and the eastern half of the MSA. These two areas have the poorest access across all three maps of healthcare facility accessibility; these areas are sparsely populated and have very few physicians, yet this is also on the edge of the study area. Residents could be traveling outside the MSA for healthcare facilities. In order to account for this possibility, healthcare facilities within fifteen minutes of the MSA border were included, yet these residents could be traveling even farther for their healthcare services. Although the results presented may account for health services used outside the MSA, accessibility still remains poor, and residents living on the periphery must travel greater distances, some even farther than thirty minutes for healthcare facilities.

Identifying the areas of the MSA that have poor access to physicians was one aspect of this research. The next area of inquiry is to understand the population related issues to physician accessibility. Larger values of the accessibility indices represent greater physician-to-population ratios and therefore are indicative of better healthcare facility accessibility. While these findings reveal good access for the majority of the MSA, certain groups may experience poorer access than others.

Before correlating the socioeconomic variables with the access indices, however, a global spatial autocorrelation statistic is computed to determine which statistical methods can be used. The choice of spatial weights can influence the findings of global autocorrelation. Therefore, different weighting schemes were tested, including first-order rook's contiguity (neighbors share a border of non-zero length), queen's contiguity (neighbors can share zero length (point) borders), k-nearest neighbors, and distance-based methods in which all observations are considered neighbors. For both the k-nearest neighbor and distance method, distances between an observation and its neighbors are computed with near neighbors having higher weights than farther ones (distance decay). The k-nearest neighbor, rook's, and queen's contiguity measures all produced roughly similar results, so the k-nearest neighbor method is used (with k = 8) because it performs well when the areas (tracts) are of differing sizes (Anselin 2003), like the tracts here.

Simple global Moran's *I* values are computed for each of the seven socio-economic variables and the three access indices; these are shown in Table 2.4 ranked from highest (positive) spatial autocorrelation to lowest. In order to account for autocorrelation, an expected value of Moran's *I* is computed to test for significance of autocorrelation. The expected value of Moran's I is $\frac{-1}{n-1}$ (Getis 2010), which for 333 observations (tracts) produces an expected value close to zero of -0.0030 under the null hypothesis of no spatial autocorrelation. In comparison to this value, all variables are significant to at least the 0.2 percent significance level using a permutations approach (Anselin, Syabri and Kho 2010) with 999 permutations. Hence, all variables exhibit strong positive autocorrelation and simply correlating them with Pearson's *r* would potentially lead to severe Type I errors when rejecting null hypotheses (Haining 1990).

Table 2.4: Global Univariate Spatial Autocorrelation Statistics

Variable	**Moran's *I***	**Significance (p-value)**
E2SFCA_Fast	0.8921	< 0.001
E2SFCA_Slow	0.8657	< 0.001
2SFCA	0.7689	< 0.001
Percent Hispanic	0.7468	< 0.001
Percent with no diploma	0.6099	< 0.001
Percent African-American	0.5386	< 0.001
Percent living in poverty	0.3152	< 0.001
Percent elderly	0.1625	< 0.001
Percent American Indian	0.1246	< 0.001
Percent with no vehicle	0.1129	0.002

The spatial autocorrelation in the various 2SFCA methods, detected by Moran's *I* and documented above, reinforces the impressions from Figures 2.4-2.6 that there are spatial clusters with good and poor access to physicians. In terms of population characteristics, the Hispanic population is the most concentrated, followed by those without high school diplomas and African-Americans. Those living in poverty are moderately clustered, while the elderly, American Indians, and those without vehicles are less clustered, though the clustering for these groups is still statistically significant.

Local spatial autocorrelation statistics are calculated with the bivariate Moran's *I*, which correlates an observation's value of one variable against the spatial lag (weighted average) of its neighbors' values on a <u>second</u> variable. This method allows for pairs of variables that exhibit spatial autocorrelation to be examined together. As with the univariate statistics in Table 2.4, a k-nearest neighbors weighting scheme is used with eight neighbors, and significance values are derived based on 999 permutations of the dataset. Each floating catchment method exhibited spatial autocorrelation and therefore, each method underwent bivariate analysis. Results for each 2SFCA methods are quite similar, so only results for the E2SFCA_Slow method are shown in Table 2.5.

Table 2.5: Global Bivariate Spatial Autocorrelation Statistics

E2SFCA_Slow and Variable	Moran's *I*	Significance (p-value)
Percent Hispanic	0.3613	< 0.001
Percent with no diploma	0.2572	< 0.001
Percent African-American	0.1975	< 0.001
Percent with no vehicle	0.1655	< 0.001
Percent living in poverty	0.1323	< 0.001
Percent elderly	0.1004	0.002
Percent American Indian	-0.0892	< 0.001

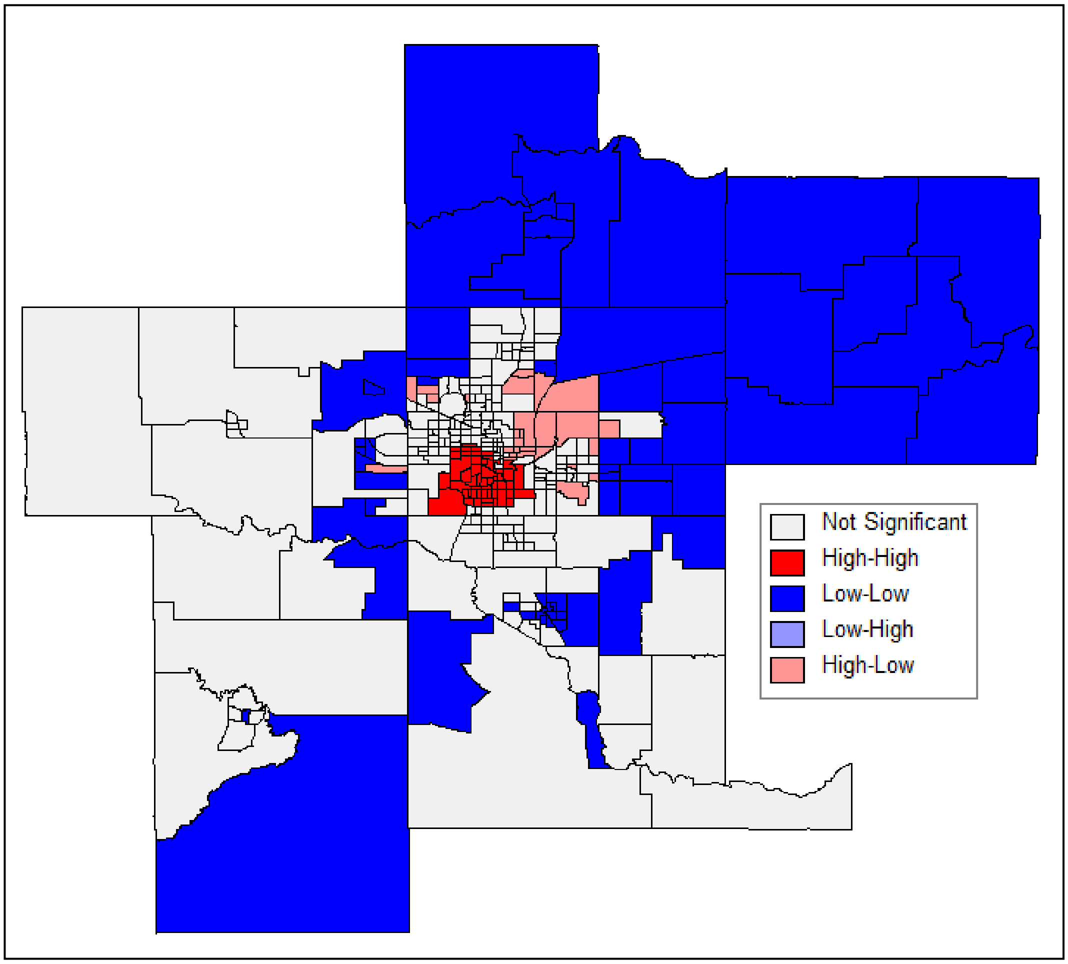
Percent Hispanic and E2SFCA_Slow have the strongest spatial association. This indicates that the Hispanic population does not experience poor physician access. The other two positive and significant autocorrelation results with E2SFCA_Slow are for the percentage of the population without a high school diploma and the percent African-American. These results paint a better picture for inner-city residents than other American cities in that these socioeconomically-disadvantaged groups correlate with areas of high physician accessibility.

The only negative correlation is for American Indians. Though this association is relatively weak, it reveals that American Indians, due to their peripheral residential patterns around Oklahoma City, have the worst access to primary care physicians and urgent care centers. However, mitigating this situation could be the use of Indian health services, which provide free or reduced cost healthcare at specific clinics. An examination of both the locations of these clinics and their usage by American Indians would be a useful follow-up study, since the methods used in this study simply quantify *potential* access and physician gaps. For all groups, emergency rooms may also provide basic care, though this study has excluded hospitals in an attempt to study just one dimension of the health care network, that of basic or routine care provision.

These results provide information on where clusters of good physician access occur with socioeconomic groups. However, it is useful to analyze locations with these socioeconomic groups to identify any potential problems of access for various population groups. As such, another valuable analysis tool is the significance map based on local statistics, showing each tract with a local Moran's I_i value that is significant at the 0.05 level or below. The value of these maps (and local statistics in general) is that they allow for four types of autocorrelation combinations to be shown visually. Positive spatial autocorrelation can manifest itself as either "high-high" patterns (hot spots) in which significantly larger than expected values of both variables are spatially contiguous or "low-low" patterns (cold spots) where significantly lower than expected values co-locate. Likewise, negative spatial autocorrelation can appear as either "low-high" or "high-low." To interpret the legends, the E2SFCA_Slow is listed before the hyphen and the spatial lag of that tract's neighbors' values of each socioeconomic variable is listed after. Figure 2.7 shows the significance map for the pairing of E2SFCA_Slow and percent Hispanic.

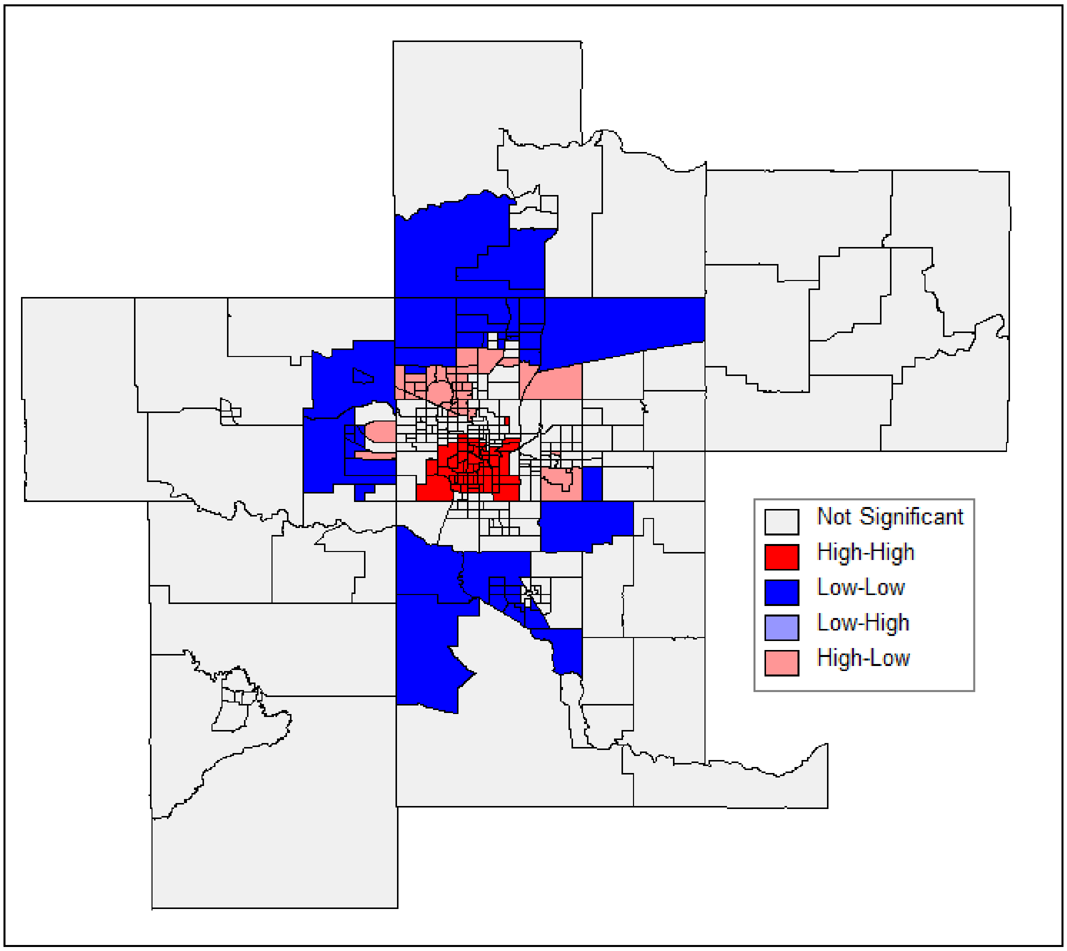
Positive spatial autocorrelation is quite apparent between these two variables. Both the dark red (high-high) and dark blue (low-low) tracts exhibit positive spatial autocorrelation, or clustering of like values. The very heavily clustered core of the Hispanic population southwest of downtown overlaps strongly with the tracts that have high E2SFCA_Slow ratios, which is a hot spot of both good access and strong presence of the population group under study. The dark blue tracts in the northwest portion of the MSA reveal areas of both small Hispanic presence and poor access to physicians. The pocket of negative autocorrelation (high-low) located in the northwest of downtown exhibits high access and low Hispanic percentages.

Figure 2.7: Percent Hispanic and E2SFCA_Slow Cluster Map



The next highest, and significant, bivariate Moran's *I* value is for the percentage of the adult population (age 25 and over) without a high school diploma. Though strongly correlated with other socioeconomic indicators, the issue of adequate education affects the choices made by residents with respect to health. The significance map for this pairing is shown in Figure 2.8. The hot spot on this map almost perfectly matches that shown on Figure 2.7. Various socioeconomic variables are correlated with each other, so locations with large concentrations of Hispanics, poverty, low educational attainment, and poor access to private transportation are all likely to co-locate. However, several

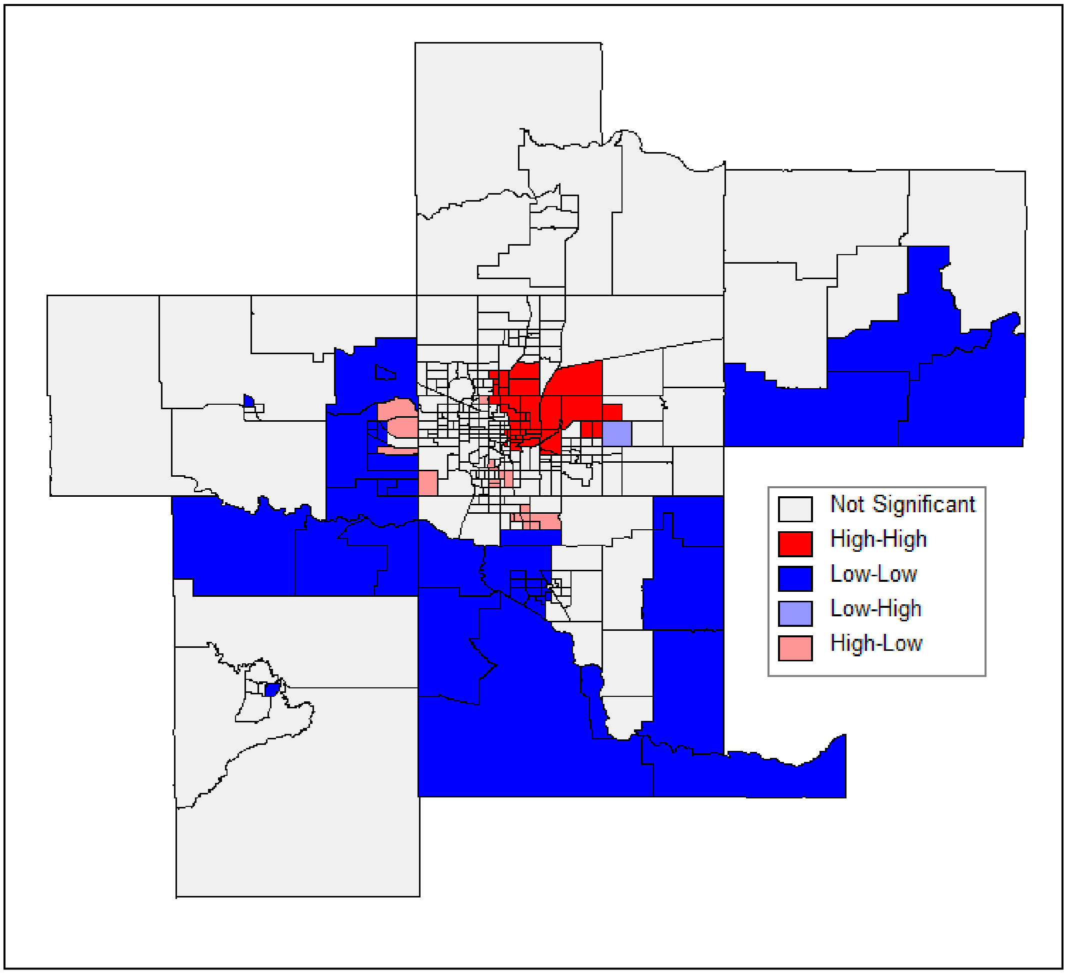
Figure 2.8: Percent with No Diploma and E2SFCA_Slow Cluster Map



negative autocorrelation areas with high access and low percentages of persons without diplomas are quite noticeable. Edmond to the north and Midwest City to the east both stand out. Edmond has a reputation for being a wealthy suburb, and Midwest City is home to Tinker Air Force Base. A surprising result with access to physicians and those without a diploma occurs with no significant results appearing on the fringe, which was a primary finding during the floating catchment results.

The final significant positive autocorrelation result is for percent African-American. This significance map is shown in Figure 2.9.

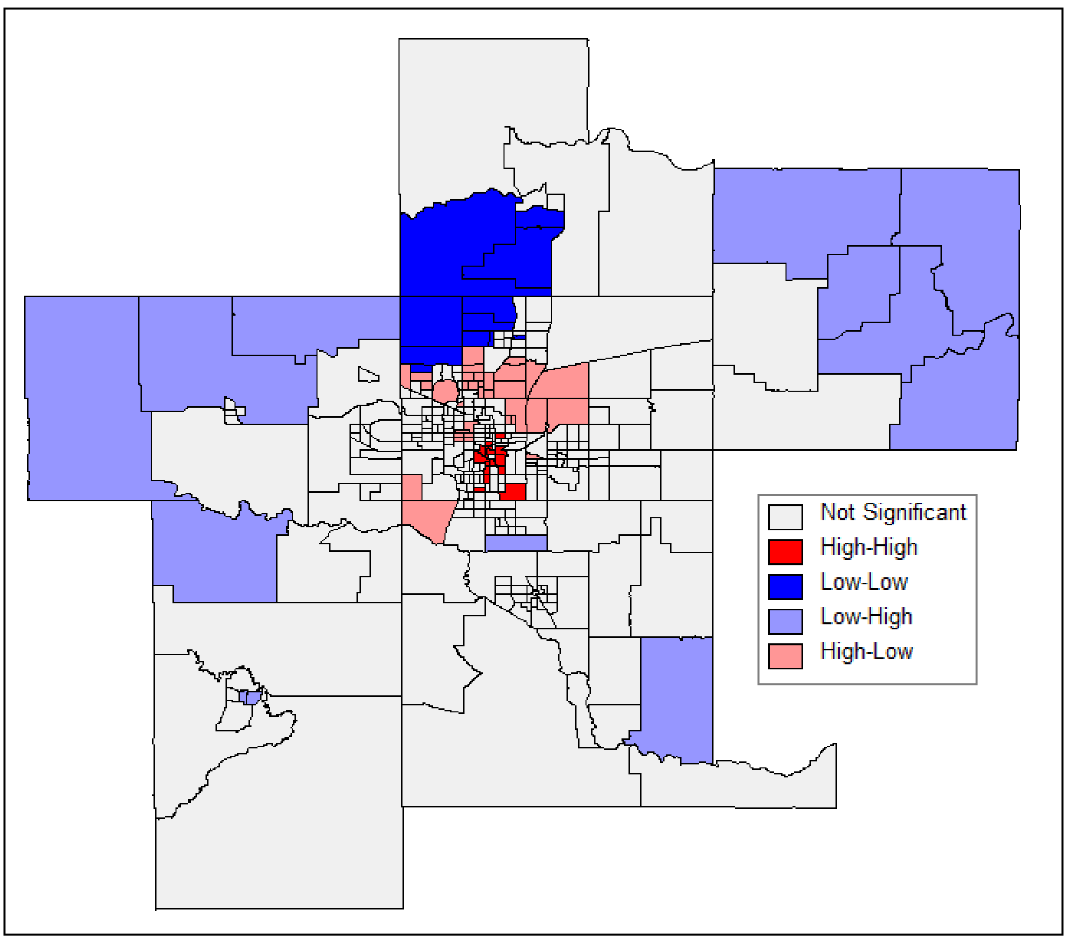
Figure 2.9: Percent African-American and E2SFCA_Slow Cluster Map



This area experiences good access to physicians, resulting in a hot spot, contrary to many previous healthcare access studies. Due to the concentration of African-Americans in the MSA, the fringe areas are revealed as having both low access as well as low percentages of African-Americans. An interesting comparison between Figures 2.7 and 2.9 reveals two contrasting hot spot zones; whereas Figure 2.7 reveals negative correlation, Figure 2.9 shows very few pockets of negative correlation.

As noted earlier, only American Indians potentially experience a physician gap, matching literature-based expectations of poor access for minorities. However, the Moran's *I* value of -0.09 is not that large and is made significant by the large sample size (333 tracts). Thus, an examination of local statistics reveals subltleties not detectable by global statistics, though overall Figure 2.10 below reveals that the area most responsible for this statistical result is the fringe. Some tracts exibihit hot spots for physician access, but the western and eastern suburbs consists of many tracts with significant low-high local Moran's *I* scores (low access and high percentages of American Indians), the one potentially disadvantaged group with respect to physician accessibility.

Figure 2.10: Percent American Indian and E2SFCA_Slow Cluster Map



Conclusion

This paper examined whether areas in the Oklahoma City MSA have a physician gap by analyzing accessibility to physicians. Rather than using a physician file with zip code information, actual physician office locations were analyzed for a better understanding of the supply and demand of health care services in Oklahoma City. Only two areas of the MSA had low accessibility values across all variations of the floating catchment methods, the eastern and southwestern parts of the MSA. These two areas would be considered physician gaps, whereas the majority of the rest of the MSA had no physician gap areas. The fringe areas were found to have poor access compared to the central city residents, which was unsurprising due to lack of population and lack of physicians. Furthermore, analyzing minority groups and low income residents revealed that only American Indians had poor access to physicians, with the majority of the socioeconomic groups having relatively good access to physicians.

Previous research has examined physician accessibility using the 2SFCA, yet the results have shown poorer access for inner-city residents. In contrast, this research has shown relatively good access throughout the inner city. Combining both demand and supply factors with the use of the 2SFCA and the E2SFCA enables a more realistic evaluation of potential accessibility. Via analysis with bivariate spatial autocorrelation techniques, only American Indians are found to have poor access to physicians in the Oklahoma City MSA among various socioeconomic variables intended to represent historically-disadvantaged groups. Incorporating advanced statistical techniques along with the 2SFCA and E2SFCA has provided an in-depth analysis of physician accessibility for Oklahoma City residents.

This research offers a first step in identifying areas with potential disparities in health. The next step is to identify where health problems are occurring within the MSA. Incorporating mortality data, insurance policies, and/or hospital discharge data would allow for better understanding of problem areas in the city and an ability to identify facilities that are utilized. Future research will address these issues and incorporate this type of health data to understand where health inequalities are occurring and attempt to reduce or eliminate these disparities. This study highlights the importance of access to physicians by incorporating actual physician locations rather than a generalized zip code location and provides an example of how different methodologies can provide planners and others with a better understanding of neighborhood accessibility to physicians.

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CHAPTER III

FOOD ACCESSIBILITY IN OKLAHOMA CITY: IS THERE A GROCERY GAP?

Abstract

This research evaluates residents' access to supermarkets in the Oklahoma City, Oklahoma Metropolitan Statistical Area (MSA). The goal is to determine whether Oklahoma City experiences a problem common to many metropolitan areas, where socioeconomically imperiled sub-groups of the population have limited access to healthy, affordable food. This is accomplished with the identification of Census tracts with poor access to grocery shopping opportunities in the metropolitan area and correlating these "grocery gaps" to concentrations of historically-disadvantaged groups. An index of accessibility using the cumulative opportunities measure is created, and this index is spatially correlated with socioeconomic data from the U.S. Census Bureau pertaining to age, education, poverty, transportation, and race characteristics that represent historically-disadvantaged groups – the elderly, the poor, and minorities. The results are similar to past research in finding that rural residents within the MSA have the worst access. Unlike research conducted in other cities, however, some of Oklahoma City's inner-city residents have the best access to supermarkets across the metropolitan area, specifically the Hispanic population. These findings are examined in light of historical population trends in Oklahoma City and in contrast to other, similar U.S. metropolitan areas.

Introduction

As cities have grown and changed through time, retail firms have had to adjust their location strategies to account for the spatial and economic restructuring of cities. Suburbanization has forced retail businesses to expand their reach into a succession of suburban rings and along transportation corridors. As population moved to the suburbs, some emptying near the center occurred in most American cities. This flight created retail voids in numerous metropolitan areas as many inner-city locations proved to be less profitable and desirable than new developments in the suburbs. In particular, this can be a problem with food stores, including chain supermarkets that have limited market areas due to the lack of variety in goods sold there and higher frequency of shopping trips for grocery items. There are many implications of poor access to supermarkets: reductions in shopping opportunities, excessive travel costs to shop, health risks because of poorer quality food, and higher costs for food purchased at small food stores or even convenience stores (Mayo 1993).

Recent literature has found inconsistent results linking access to retail food and various indicators of health or socioeconomic status, both within and between countries, requiring case studies to uncover local patterns. Morland, Roux and Wing (2006) found higher rates of obesity, overweight individuals, and hypertension among residents living in Census tracts without a supermarket. Poor supermarket access has been linked with low-income, inner-city, and minority residential areas in the United States (Morland et al. 2002, Zenk et al. 2005, Morland, Roux and Wing 2006, Russell and Heidkamp 2011), though a recent study in Toledo did not (Eckert and Shetty 2011). Additionally, rural areas are often poorer than nearby urban areas, and while some research has found that small-town and rural residents have poor access to supermarkets (Powell et al. 2007), others have found sufficient access there (Sharkey, Horel and Dean 2010). In the United Kingdom, poor food accessibility occurs in suburban locations rather than in the central city (Clarke, Eyre and Guy 2002, Wrigley 2002), while in Canada most urban areas have good access to food (Apparicio, Cloutier and Shearmur 2007).

Due to the conflicting research findings reviewed above, this research explores supermarket accessibility within the Oklahoma City MSA to determine how this city fits into the continuum of North American urban places with respect to food availability. Oklahoma City is chosen as the study area because of its poor rankings in many health indices (Muchmore 2010), its unique traits vis-à-vis other measures of access and equity (Comer and Skraastad-Jurney 2008), and its usefulness as a representative, south/western-U.S. metropolitan area upon which to conduct a case study. Understanding how food accessibility differs for a variety of residents, including the rural-urban divide, the poor, the elderly, and minorities, will ultimately provide policy-makers at the state and federal levels with information about which neighborhoods of historically-disadvantaged groups, if any, have poor supermarket accessibility. In the Oklahoma City MSA (and the state of Oklahoma in general), health problems are abundant, including high rates of heart disease, obesity, and hypertension (Muchmore 2010). Evaluating the availability of healthy food for residents will promote a better understanding of how a lack of access to healthy food might be related to recurrent health problems and what steps, if any, public agencies, private entities, and the citizenry can take to improve overall health levels of the residents.

Background

Emergence of "Grocery Gaps"

Access to healthy food is an important component of understanding health inequalities. Most research has found that both who you are (genetics) and where you live (environment) influences your health (Pickett and Pearl 2001, Prentice 2006). In addition, the idea that poorer areas tend to have less access to a wide variety of retailers, including food sources, has led to increased scrutiny of the spatial unevenness of retail food availability (Macintyre 2007). A brief history of grocery retailing reveals how this pattern emerged in American cities during the 20th Century.

Technology caused a tremendous transformation of the grocery business as with most other retail endeavors in the U.S. During the first half of the 19th Century, food was purchased from either street vendors or public markets. These markets evolved into general stores that sold dry goods such as sugar, tea, and oatmeal and eventually became the grocery stores of today (Mayo 1993). The grocery store format evolved due to a variety of technological catalysts, including refrigeration, transportation improvements, and increased use of personal automobiles, all of which also contributed to increases in store size (Walsh 1993). The growing density of people and better distribution systems supported the emergence of larger stores. With mass production becoming commonplace due to the emergence of companies like Campbell, Armour, and Nabisco, grocers could move out of the public market stall and into stores of their own, which could then turn into multiple stores. Among the first firms to do this were A&P and Kroger (Mayo 1993). Expansion via chain stores helped shopkeepers keep prices low by buying in bulk, saving on advertising expenses, and earning higher profits due to lower overhead costs.

In the mid-20th Century the middle class began its exodus from the central city, and these areas became undesirable for retailers due to low population densities and low profit potentials. Instead, low land costs and growing populations on the urban fringes lured retailers to develop new suburban markets (Shaffer 2002). Many small stores closed because they could not compete (Alwitt and Donley 1997) because of the larger formats of grocery stores that emerged in the second half of the 20th Century (e.g. Wal-Mart Supercenters). This created gaps in access to grocery shopping opportunities in the inner and central cities. Areas that once had food stores were soon devoid of them. In America, this absence of food stores is termed a "grocery gap" (Shaffer 2002) and in Britain it is known as a "food desert" (Wrigley, Warm and Margetts 2003). When supermarkets moved to the suburbs, inner-city residents, who generally have poor mobility, found fewer shopping opportunities (Mayo 1993). This situation, coupled with low incomes, means finding healthy food could be problematic and lead to poor food choices, increasing health risks and malnutrition. Malnutrition contributes to many other health problems, including heart disease and cancer (Steinmetz and Potter 1996, Franceschi et al. 1998, Fernandez et al. 2000).

In the U.S., the grocery gap has been found in inner-city areas with high concentrations of minorities. In *The Persistence of L.A.'s Grocery Gap,* Shaffer (2002) found inner-city residents had fewer options for obtaining healthy food, leading to serious health problems like obesity. Shaffer's study also showed that in addition to income level influencing the presence of supermarkets, the racial makeup of the area was also a factor relating to store presence (Shaffer 2002). Similar results were found in Dallas, with low income residents and African-Americans having the worst access to grocery stores (Berg and Murdoch 2008). In Detroit, the racial makeup of the area, specifically African-American neighborhoods, had more of an impact on access than income levels (Zenk et al. 2005). Morland et al. (2002) studied several U.S. cities and found that heavily African-American residential areas had just one-fourth as many supermarkets as predominantly white areas.

However, the grocery gap exists neither solely in urban areas nor strictly for minorities. Rural residents also experience limited supermarket accessibility. Retail opportunities tend to be farther away from rural residents and vehicles are needed to reach these opportunities (Furey, Strugnell and McIlveen 2001, Sharkey and Horel 2008). Also, low-income residents are not the only ones experiencing poor food access and malnutrition; other disadvantaged consumers suffer from these problems as well. Those who are disabled, ill, without a car (Hallett IV and McDermott 2011), single parents, unemployed, and elderly are disadvantaged (Westlake 1993). Whether income, race, or some combination of factors is responsible for limited opportunities, these gaps serve to isolate the residents both economically and socially, as a much narrower range of business or entertainment opportunities exists nearby (Westlake 1993, Piacentini, Hibbert and Al-Dajani 2001). For example, Hall (1983) found that in areas dominated by the elderly and by African-Americans, food cost more, was of poorer quality, and featured less selection.

Lack of access also causes increases in both travel costs and food prices. Since lower income consumers have less to spend, any type of increase in the cost of a good has severe consequences. High costs can force low-income consumers to sacrifice other necessities, like shelter or clothing (Shaffer 2002). The same situation can occur when gas prices rise and healthy food may be sacrificed by those with limited spending power (Shaffer 2002). Hence, the study of food availability vis-à-vis access is a multi-faceted problem involving both characteristics of the population and the study area. Various approaches to this type of study are present in the literature and are reviewed next.

Process Measures and Outcome Measures

Living in close proximity to a retail store, medical facility, or community center should make it easier to access that place. Yet, some studies have revealed that even when access is improved, consumers still may not take advantage due to prior habits or monetary issues (Wrigley et al. 2002, Wrigley, Warm and Margetts 2003). As a consequence, methods have been developed to study this phenomenon from two primary perspectives, examining both the objective spatial characteristics of the study area and the subjective behavioral choices of the studied population. Correspondingly, accessibility studies are typically based on either *process measures*, which require aggregate socioeconomic data and the locations of facilities to evaluate the spatial dimensions, or *outcome measures*, which require surveys of the population to understand the behavioral dimensions (Guy 1986). Due to the time, cost, and self-reporting issues associated with surveys, this research focuses on process measures to permit a detailed analysis of conditions across the MSA and to represent its entire population as completely as possible by using economic and demographic Census data.

In addition to population traits, process measures require some delineation of consumers' distance thresholds for various goods and services in order to determine the set of accessible facilities for each neighborhood. For example, convenience stores attract customers from a limited distance, while a regional mall has a much larger market area due to consumers' willingness to travel farther for those opportunities (Wrigley, Guy and Lowe 2002). Approaches that use travel times or simple distances to a facility are the most common (Joseph and Phillips 1984, Zenk et al. 2005) as are methods that identify the number of opportunities within a specified buffer (Russell and Heidkamp 2011).

The approaches that use travel time require specific distance thresholds to compute access levels. Lacking exact values for individuals derived from surveys, this research will address the entire metropolitan area with system-wide, aggregate distance values. However, a wide assortment of values has been used in past research on grocery stores and must be assessed. Clarke, Eyre, and Guy (2002) used a 500 meter buffer around retail food stores in Great Britain. Smoyer-Tomic et al. (2008) used four different distances (500, 800, 1000, and 1500 meters from Census block centroids) in Edmonton, Canada. Witten, Exeter, and Field (2003) used a 2000 meter buffer for supermarket access in New Zealand. In Dallas, a one mile radius around each supermarket was employed (Berg and Murdoch 2008). In rural areas, in contrast, a consensus seems to have coalesced around ten mile buffers (Morton and Blanchard 2007, Sharkey and Horel 2008, McEntee and Agyeman 2010, Hubley 2011). These studies, taken as a group, imply that each study must derive or defend a given buffer/threshold/bandwidth distance that is appropriate for that study area, and that no uniform value will ever emerge. In this vein, some effort will be devoted later to choosing this distance.

Measuring "Access" to Facilities

In addition to understanding the nature of grocery gaps and how they emerge, and the distance thresholds that delimit consumer behavior regarding grocery stores, the issue of how to detect, measure, and differentiate unequal access to localized facilities (including grocery stores) must be resolved. Guy (1983) reviewed several accessibility measures that can be applied to retail location problems, including a gravity measure, a Gaussian measure, and the Cumulative Spatial Opportunity (CSO) measure. Though an older work, much current research still makes use of these measures and Guy remains frequently cited, indicating a broad acceptance of the family of models that are reviewed below. Each of these measures produces an index of accessibility that can be mapped and statistically analyzed, while retaining unique features that measure accessibility in different ways. All models ultimately descend in some way from the gravity model, with distance decay impeding access. Models differ based on the specific distance decay function used and the many ways that access to opportunities (here, grocery stores) can be tabulated.

A measure directly based on the gravity model is the simplest and serves as a useful benchmark against which to evaluate more complex methods. The measure can be written as:

$$A_i = \sum_j S_j d_{ij}^{-\beta}$$

where A_i is the accessibility index for location i, S_j is the 'size' of the opportunity at location j, d_{ij} is the distance from location i to opportunity j, and β is a distance decay parameter (Guy 1983). A fuller discussion of the dataset occurs later, but locations i in this study will be Census tracts and opportunities j will be grocery store locations. Often, S_j is set to one and all stores are treated as identical entities (Guy 1983), an approach adopted here, but it could also measure square footage, the number of establishments (such as in a mall), or some other useful measurement of size. Overall, however, this model is quite basic and lacks the means to assess access in a more nuanced way.

An improvement to the simple gravity model is a Gaussian measure. Gaussian measures are generally preferred because they result in non-linear distance decay effects, giving much heavier weights to closer opportunities. Weights decline at a rapid pace the farther out an opportunity *j* is from location i. A standard Gaussian formulation is:

$$A_i = \sum_j S_j \exp - \frac{1}{2} \left[\frac{d_{ij}}{d_*}\right]^2$$

where d_* is the distance from point *i* at which the rate of decline in accessibility has achieved its most rapid rate (the inflection point on the distance decay curve). Beyond d_*, the decline in accessibility becomes more gentle as it approaches the distance axis asymptotically (Guy 1983). However, the calibration or justification for values of d_*can be as challenging as estimating β in a regular gravity model.

The cumulative spatial opportunity (CSO) method advances upon a basic Gaussian measure by limiting analysis to a realistic subset of opportunities. Rather than computing the "pull" or influence of <u>every</u> opportunity *j* on the access level at *i*, the CSO employs a bandwidth distance *D* that limits the consideration of opportunities to only those within a certain distance from location i, where *D* is typically set to some value representing the likely maximum walking or driving distance consumers will travel for the good. Thus, the CSO measure is based only on the distance decay for a smaller number of realistic distances consumers might travel, and is also influenced only by the number of opportunities available to location *i* within the *D* threshold; this number is expressed as $O_i(D)$. As with all measures, near opportunities have higher weight than farther ones. The CSO measure can be expressed as (Guy 1983):

$$A_i = O_i(D) \left[D - \frac{\sum_{j=1}^{O_i(D)} d_{ij}}{O_i(D)}\right]$$

The biggest drawback of the CSO method is that it is sensitive to the bandwidth value *D.* If the distance is either too large or too small, the numbers of opportunities may be too many or too few, respectively. Past studies provide some guidance in this area, but some examination of the study area is needed to arrive at a satisfactory value of *D* for this study. The first part of the analysis later in this paper employs descriptive methods to accomplish this task, while the second part looks for statistically significant relationships between the CSO scores and socioeconomic characteristics across the MSA in an effort to identify spatial associations between grocery gaps and historically-disadvantaged populations. It is tempting to simply correlate CSO scores and socioeconomic variables to detect large positive or negative correlations and draw conclusions from those results. However, datasets like the one used in this study typically exhibit spatial autocorrelation, a phenomenon in which the value of an individual observation is very similar to (positive autocorrelation) or very different from (negative autocorrelation) its neighbors. This phenomenon underpins the concepts of neighborhood, region, and culture, and is very important in geography. However, autocorrelation violates a basic assumption of many statistical methods like correlation and regression that would be useful tools for documenting spatial associations between access and socioeconomic status.

Spatial Autocorrelation

Statisticians, geographers, and others have spent decades devising methods to measure, attenuate, and/or incorporate spatial autocorrelation into their research, much as economists have built strong research expertise working with data that exhibit temporal autocorrelation. If autocorrelation levels are low, standard statistical methods can be employed. If autocorrelation levels are high, however, any inferences based on standard methods will be invalid as the presence of autocorrelation underestimates standard error values, which inflates t-test values for Pearson's r.

This problem of deflated standard errors occurs because basic statistics assume observations are independent; for most spatially-referenced variables this assumption is violated. Places near to one another likely exhibit similar values, a result of other spatial processes at work that are not being directly measured (i.e. culture, history, political economy). Thus, a strong correlation between two non-spatial variables may actually be caused by mutual dependence on an omitted (and possibly un-measurable) variable that captures the spatial characteristics of the study area and not because of a direct, causal link between them (Haining 1990). Such spatial characteristics may relate to aggregation and scale effects as well as larger population processes that drive people to segregate into enclaves of similar status. This is the danger of spatial autocorrelation in virtually any type of inferential statistical analysis involving spatial (or temporal) data.

As a result, the effects of autocorrelation must be mitigated in some fashion. One approach is to eliminate the effect from the dataset in order to use basic statistical methods like Pearson's r. Haining (1990) outlined a lengthy procedure to estimate the effective sample size n in the presence of autocorrelation. The effective sample size is smaller than the original sample size n in the presence of positive spatial autocorrelation by removing the information redundancy that exists when spatial autocorrelation is present. This approach, while intuitively appealing as it permits direct use of traditional t-test formulations by counteracting standard error deflation, is in practice extremely cumbersome (Haining 1990).

Alternatively, autocorrelation can be measured directly and, using methods developed over the past two decades, exploited to more deeply understand the relationships between the variables in a study. This is the approach used here; rather than “wash” autocorrelation out of the dataset, we capitalize on it as a means of examining the relationship between access to grocery stores and the socioeconomic traits of the MSA vis-à-vis explicit incorporation of the influence of “neighbors” on the behavior of these variables at specific locations in the study area.

Spatial autocorrelation must first be measured. The simplest approach is to use a global statistic. Global statistics analyze the entire study area and consist of a single value, just like Pearson’s *r* is a single value representing an entire dataset no matter how many observations exist. Moran’s *I* is the most well-known of the global measures, and behaves very much like Pearson’s *r* with *I* values approaching 1.0 indicating positive autocorrelation and values approaching -1.0 indicating negative autocorrelation (Moran 1948, 1950). This statistic’s format is also very similar to the Pearson product moment correlation coefficient, by design. However, Moran’s *I* incorporates space via a spatial weights matrix, and instead of finding the correlation between two variables, it measures the correlation of one variable with itself (Getis 2010), thus the term *auto* (self) correlation. Because the observations are spatially referenced, a spatial weights matrix is needed that identifies the neighbors of each point in the dataset. Many other spatial autocorrelation measures have subsequently been developed, but most share the basic format of a cross product between a function that quantifies the similarity of values of a given variable and a spatial weights matrix (Fortin and Dale 2009).

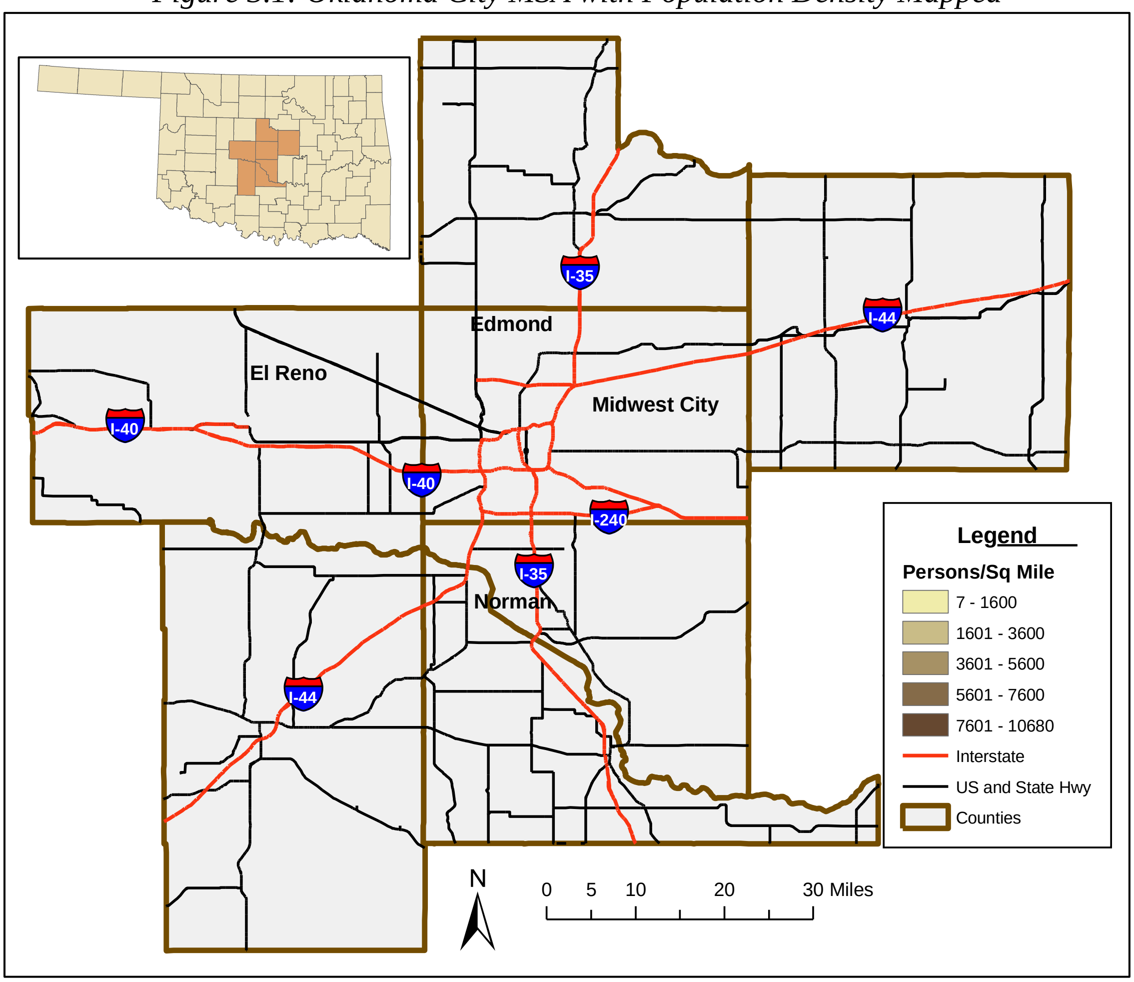
Though useful, global statistics are limiting because local variations in the dataset can be masked (Fotheringham, Brunsdon and Charlton 2000). For example, the global Moran's I for an area could be close to the expected under the assumption of no autocorrelation, but pockets of positive and negative autocorrelation exist that cancel each other. To uncover local variations that might create this situation, local versions of spatial statistics have been developed to detect these patterns, including Moran's I_i (Anselin 1995) and the family of G_i statistics (Getis and Ord 1992), among others. In addition to avoiding problems of overlooking serious spatial autocorrelation in a dataset, local statistics are calculated for each sub-unit of the study area (here, tracts), which can be mapped and studied (both visually and statistically) for clusters of observations exhibiting high levels of spatial autocorrelation. To facilitate this analysis, the software package *GeoDa* (Anselin, Syabri and Kho 2010) is used, which easily calculates these spatial statistics and related graphics.

This paper represents just one way to examine this problem. Given the large number of grocery gap definitions (McEntee 2009), accessibility measures, statistical methods, and available data sources, consensus is unlikely to emerge in this field despite the hopes of McEntee and Agyeman (2010). However, much recent research remains relatively descriptive in both the literal and statistical sense of the word, and so this paper represents a methodological advance as well as providing a case study of one MSA. At this point, it is useful to define the study area, describe the data involved in this study, and then derive a bandwidth value that makes sense for this study area, ultimately leading to the main goal of evaluating which disadvantaged groups (if any) live in grocery gaps.

Study Area

Oklahoma City is chosen for study (Figure 3.1) due to numerous abysmal health indicators relating to food availability and consumption. The state ranks last among all fifty states in the percentage of adults who eat five or more servings of fruits and vegetables daily; over one-third of the population is overweight; and in 2004, Oklahoma ranked worst among states in the percentage of households that go hungry. Furthermore, a recent study found that thirty-two of the seventy-seven counties have a grocery gap (McDermott et al. 2006). This paper narrows the focus to the largest city in the state to identify neighborhood (tract)-level grocery gaps.

Figure 3.1: Oklahoma City MSA with Population Density Mapped



The MSA has just over 1.3 million people, contains the state's largest city, and is made up of seven counties in central Oklahoma (U.S. Census Bureau 2010). It was the fastest growing city in Oklahoma between the 2000 and 2010 Censuses and since 2000 has experienced an increasing number of minorities, especially Hispanics (U.S. Census Bureau 2010).

The central business district is located in the heart of Oklahoma City and consists of the typical collection of office buildings, hotels, conference centers, plus an entertainment district known as Bricktown. Historically, very few people have lived in the inner city, and although there has been an increase in construction of central city housing, downtown or inner-city locations remain relatively lightly populated. As a result, retail establishments other than restaurants are also lacking. Previous research has found that inner-city neighborhoods have the worst access, such as the central city in Detroit (Dai 2010). However, low population levels in downtown Oklahoma City will likely mitigate strong evidence of a grocery gap. Additionally, the MSA consists of extensive rural areas with low population densities and low numbers of minorities. Therefore, supermarket accessibility indices for Oklahoma City will likely highlight these rural areas as having poorer access than urban areas.

No research on supermarket access in Oklahoma City has been found. In 2006, each county in the state was analyzed for food accessibility and food security (McDermott et al. 2006), but no research analyzes food accessibility at the neighborhood level. Some research has examined accessibility to parks (Comer and Skraastad-Jurney 2008) and public facilities (Knox 1982) in Oklahoma City. In both cases, accessibility was compared to socioeconomic and demographic data. For parks, tracts with better access corresponded to Hispanic and low-income population clusters, whereas heavily African-American and Asian tracts had less access to parks (Comer and Skraastad-Jurney 2008). For public facilities access, Knox (1982) analyzed seventeen different facilities, such as banks, dentist offices, golf courses, physician offices, and department stores. He found that few residents had good access to all facilities. Residents living in the inner city had good access to employment opportunities but very low access to hospitals, libraries, and community centers. Residents living in suburban areas, in contrast, had good access to golf courses and physician's offices but not employment opportunities (Knox 1982).

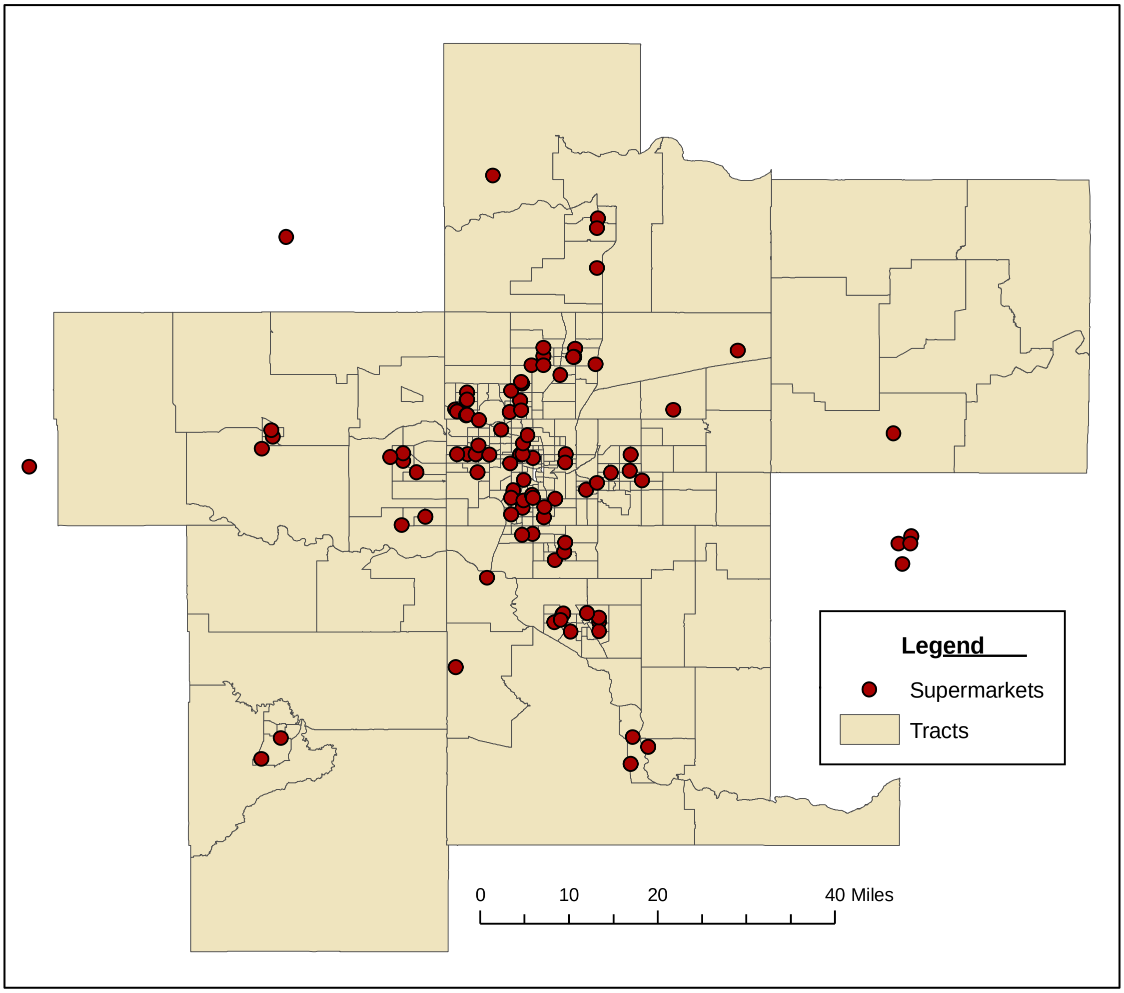
Data Sources and Summary Measures

Grocery Store Locations

Supermarkets that offer fresh fruits and vegetables, fresh meat (such as ground beef, pork, and chicken), and a wide variety of staple foodstuffs, will be used in this research due to their greater selection of food and lower prices than smaller retailers such as convenience stores. Chain stores without a fresh meat selection, such as regular Target stores, were excluded due to their reduced availability of food items, as were convenience stores, fast food stores, and specialty food stores (ethnic, organic, or gourmet). While this introduces some bias, the majority of consumers get their groceries from a supermarket rather than a convenience store (Berg and Murdoch 2008).

A shapefile of food retailers was obtained from a retail source and verified with site visits and the telephone directory. In order to mitigate edge effects, supermarkets that were within 20 miles of the edge of the MSA were included to allow for the possibility of residents living near the MSA's edge to travel outside for their food shopping. These decisions result in a dataset with 104 supermarkets (Figure 3.2). As noted earlier, each supermarket is weighted equally, though the methods permit weighting of each location by store size, selection, or other attractiveness measures.

Figure 3.2: Oklahoma City MSA Supermarket Locations



Demographic and Socioeconomic Data for Census Tracts

Grocery store locations represent one half of the necessary information for a process measure approach, while social and demographic information about the population comprises the other half. The choice of a process measure approach in this study necessitates the use of Census Bureau data, which then requires a choice of spatial units for analysis as there are several feasible options: blocks, block groups, or tracts.

Census tracts tend to exhibit similar socioeconomic characteristics (Luo and Qi 2009) so this study uses tracts as proxies for true neighborhoods. While the Oklahoma City MSA encompasses 334 total tracts, one downtown tract (1031.02, which is immediately north of the Oklahoma City arena (Ford Center) and which comprises about 16 city blocks) has no population and is excluded, leaving 333 usable observations.

Past research in the literature provides guidance on identifying specific population groups in the study area that are most at risk for poor supermarket access. Minority populations have been found to have poorer access in previous metropolitan studies and so the percentages of African-Americans, American Indians, and Hispanic populations are included in the study. Additionally, socioeconomic factors such as income and educational attainment may contribute to residents having unequal retail opportunities and these traits are included in this study by using the percentage of residents living in poverty and the percentage of adults age 25 and older who lack a high school diploma. Access to healthy food is also important throughout our lifespan and elderly residents are more at risk for living in grocery gaps, so the percentage of population aged sixty-five and older is also analyzed. Finally, transportation access can be a critical factor in the range of retail options available to an individual, and so the percentage of persons without a personal vehicle is included.

With the elimination of the Census long form in 2010, most socioeconomic data are now collected annually via the American Community Survey (ACS). In order to avoid year-to-year data anomalies this study uses tract-level data from the 5-year ACS based on a sample of approximately two million people nationwide and conducted from January 1, 2005 to December 31, 2009 (U.S. Census Bureau 2009).

Table 3.1 summarizes the ACS data used in this study, both the variables of interest and the larger populations from which they are drawn. For example, poverty is based on a subset of the total population for whom poverty is determined, not the entire population, as individuals living in group quarters (prisons, mental health facilities, etc.) are excluded from the computation. Similarly, educational attainment of a high school diploma is conventionally computed for only those residents age 25 and older, and car ownership is computed only for those persons age 16 and older.

Table 3.1: Variables with Table Number and Definition from ACS 5 Year Estimates

Variable of interest	**ACS table**
Percent African-American	B02001 – Race
Percent American Indian	B02001 – Race
Percent Hispanic	B03002 – Hispanic or Latino by Race
Percent with no diploma	B08141 – Sex by Age by Educational Attainment for the Population 25 Years and Older
Percent in poverty	B17001 – Poverty in the Past 12 Months by Sex by Age
Percent elderly	B01001 – Sex by Age
Percent with no vehicle	B08141 – Means of Transportation to Work by Vehicles Available for the Population 16 Years and Older

Transportation Network Data

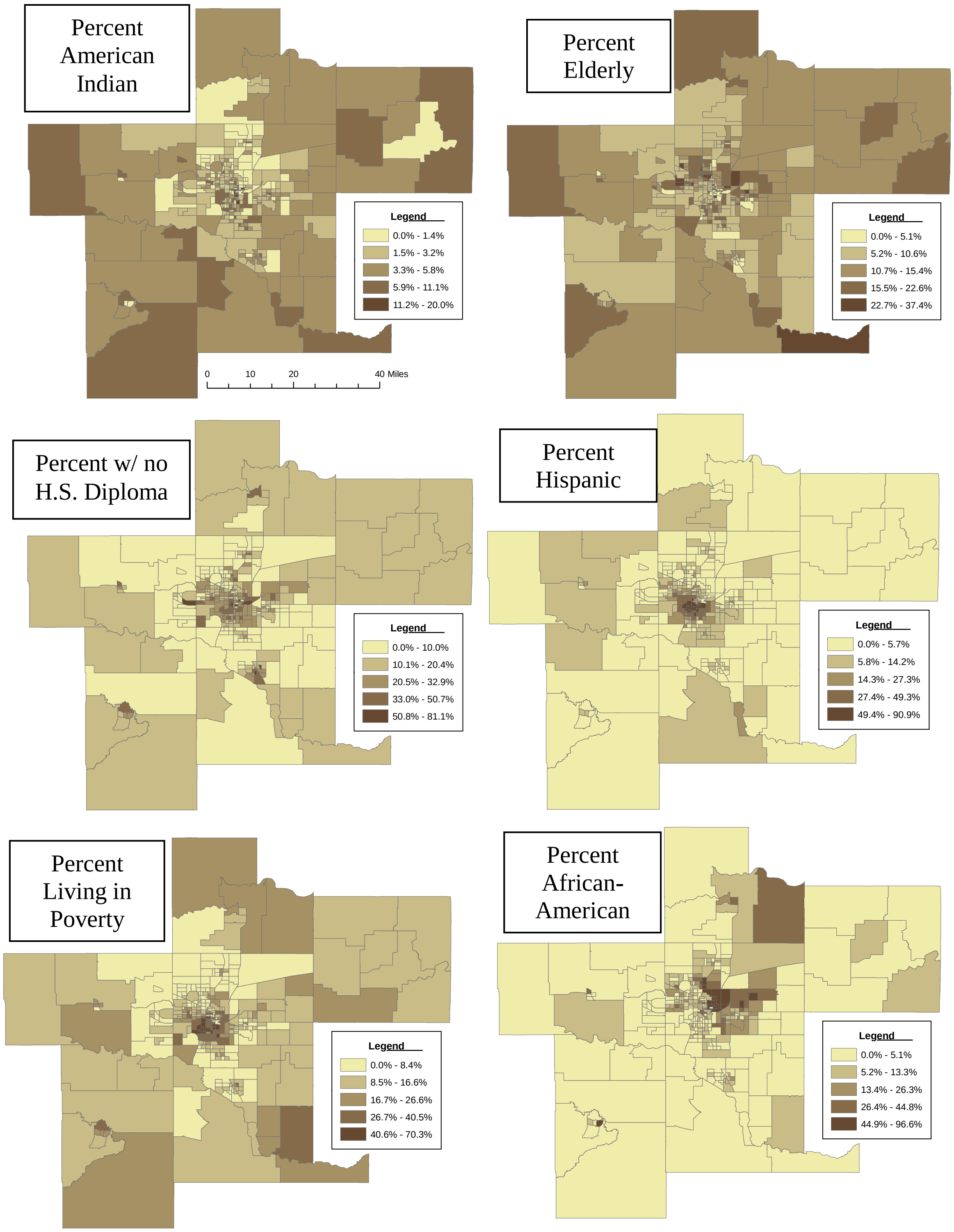
A road network file for the Oklahoma City MSA was obtained from the Oklahoma Center for Geospatial Information (OCGI 2010).To determine neighborhood-level exposure to supermarkets, ArcGIS 9.3 (ESRI 2009) and its Network Analyst extension was used to calculate the distances between supermarkets and tract centroids. The use of spatial aggregates instead of individual households introduces some bias into the research, but is unavoidable given the nature of the Census data and it is a common approach in the literature (Apparicio, Cloutier and Shearmur 2007, Sharkey and Horel 2008, Russell and Heidkamp 2011).

Oklahoma City Overview

The average Oklahoma City MSA population across the 2005-2009 ACS timeframe was 1,191,174 persons (the official 2010 Census figure was 1,322,459) spread over 6300 square miles, a population density slightly over 200 persons per square mile. African-Americans and Hispanics comprise 9.9 and 9.5 percent of the population, respectively. Though not mutually exclusive, these two groups are quite segregated into two distinct parts of the city, African-Americans being concentrated to the east of the downtown core near the state capital and Hispanics clustered southwest of the downtown area. With reference to non-racial/ethnic traits, the MSA is 11.7 percent elderly, has 14.9 percent of its population living in poverty, 12.6 percent of its adult (age 25 and over) population lacks a high school diploma, and just 2.1 percent of persons age 16 and over does not own a vehicle. Finally, though the state of Oklahoma has a strong American Indian presence, just 3.2 percent of the MSA population self-identifies as such.

Spatial patterns of these variables are illustrated in Figure 3.3. Each map is classified by natural breaks to highlight extremes within each variable/map, so the maps cannot be compared to each other directly for the purposes of identifying higher or lower percentages of the phenomena depicted based on shading. Also, a map of vehicle ownership is omitted. Just two percent of the MSA population lacks a vehicle, and in 85 percent of the tracts less than 5 percent of the population is without a vehicle. It is therefore concluded that there is very little spatial diversity in this variable.

Figure 3.3: Socioeconomic and Demographic Variables in the Oklahoma City MSA



Results

In order to distinguish areas of better or worse access to grocery stores across the Oklahoma City MSA, accessibility is analyzed in two complementary ways. Due to the importance of the distance threshold (bandwidth) upon which the CSO method operates, some effort is devoted to triangulating on a value of *D* in the CSO equation that adequately represents maximum grocery shopping travel distances for the typical consumer. To this end, a descriptive, preliminary measure of grocery access is developed. This approach will both provide a simple means for assessing access and summarizing socioeconomic statistics, as well as provide some guidance as to a reasonable value of *D* for the CSO method upon which comprises the primary means to quantify and statistically evaluate accessibility to supermarkets. Once computed, patterns of CSO values are spatially correlated with socioeconomic indicators to determine if any historically-disadvantaged groups experience poor access and therefore may be at risk of a variety of poor health conditions as noted earlier. This paper thus serves as both a case study for the MSA as well as a template for how other metropolitan areas in the U.S. and beyond could be studied.

Preliminary Assessment of Supermarket Access

Street network distances of 1, 3, 5, and 10 miles between supermarkets and tract centroids are used to categorize all 333 tracts based on access to supermarkets, and then summary socioeconomic statistics are tabulated within each category. These mileages capture the variation in accessibility within the city as well as the rural areas on the fringe of the MSA.

Five classes of supermarket access are created, with Category 5 representing the best access and 1 representing the worst. To slightly increase the sophistication of this approach, a two-level classification decision tree is used. Distances from each centroid to the closest and second closest supermarkets are tallied and tracts are categorized based on the rules given in Table 3.2. For example, if a tract has three stores located within one mile for the centroid, its accessibility level would be in Category 5. However, a tract with all three stores located two miles away would fall into Category 4. In this manner each tract receives a score between 1 and 5.

Table 3.2: Level of Accessibility to Supermarkets

Level of Accessibility	**Closest supermarket**	**Next closest supermarket**
5 – Excellent	Within 1 mile	Within 3 miles
4 – Good	Within 3 miles	Within 5 miles
3 – Average	Within 5 miles	Within 10 miles
2 – Poor	Within 10 miles	Farther than 10 miles
1 – Bad	Farther than 10 miles	Farther than 10 miles

Figure 3.4 shows the accessibility to supermarkets for the Oklahoma City MSA using the five categories described above. The central corridor exhibits the highest levels of accessibility. Even though the pattern does not resemble concentric rings, the best access is found in the central city, and then slowly decreases towards the fringes of the city. Most notably, rather than seeing the worst access in the central city, as has been the case in much of the literature, the map reveals unexpected results with the worst access areas located on the fringe. These rural areas of the MSA have “bad” access and are potential grocery gap locations. Although there is a strong concentration of stores in the central corridor, only one-third of tracts exhibit “excellent” access.

Figure 3.4: Level of Accessibility to Supermarkets

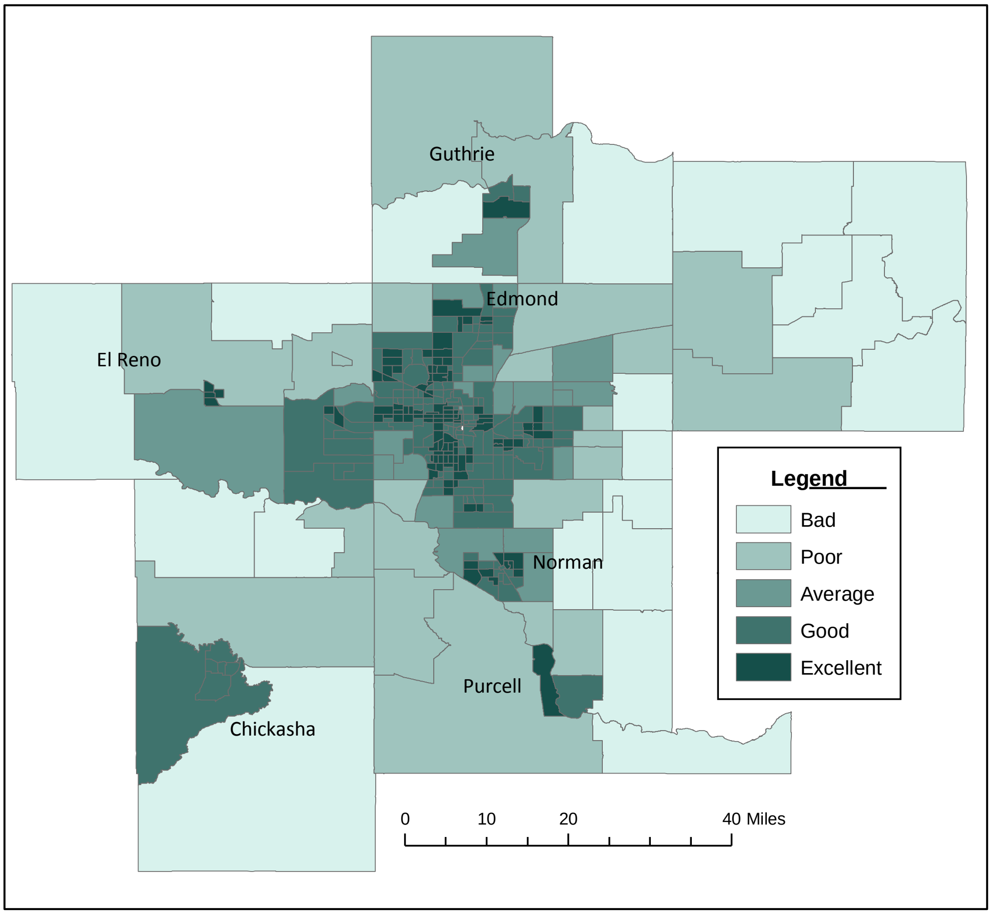


Table 3.3 lists the five levels of accessibility and corresponding descriptive statistics in each level. The top two levels of access together contain 81 percent of the MSA tracts and 75 percent of the population, the highest percentages of residents living in poverty, and the highest minority populations. Just 13 percent of tracts (17 percent of the population) have accessibility levels considered “poor” or “bad” with this metric. For tracts that fall into the “excellent” category, almost 362,000 residents have access to a supermarket within one mile. Thus, contrary to some studies of metropolitan food deserts, most inner-city residents in Oklahoma City have very good levels of accessibility.

Table 3.3: Level of Accessibility with Descriptive Statistics

Variable	**5: Excellent**	**4: Good**	**3: Average**	**2: Poor**	**1: Bad**
Percent African-American	11.2%	12.2%	9.7%	1.4%	2.8%
Percent American Indian	2.9%	2.9%	2.4%	4.5%	4.7%
Percent Hispanic	15.1%	8.9%	4.5%	3.3%	3.6%
Percent with no diploma	15.4%	11.5%	8.6%	10.9%	14.0%
Percent living in poverty	17.9%	15.5%	8.9%	9.2%	12.7%
Percent elderly	12.8%	11.1%	10.3%	11.7%	12.4%
Percent with no vehicle	3.23%	2.04%	0.50%	0.66%	0.73%
Number of tracts (% of total)	112 (34%)	157 (47%)	22 (7%)	23 (7%)	19 (6%)
Population (% of total)	361,997 (30%)	536,368 (45%)	85,829 (7%)	117,633 (10%)	89,347 (%)

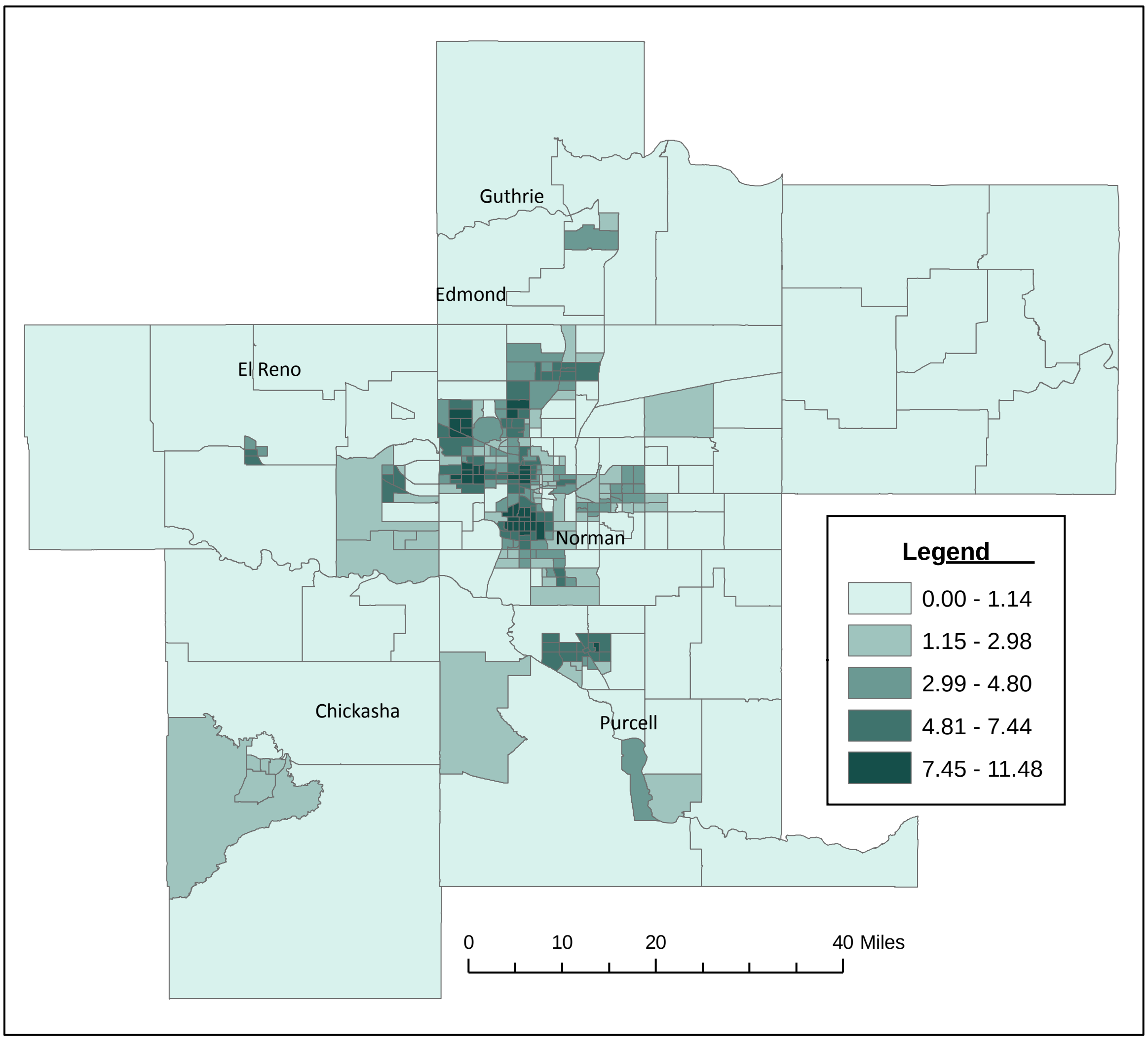
A further benefit of this preliminary analysis is the ability to determine a reasonable distance threshold for use in the CSO method. With three-fourths of the MSA population having either its first or second closest supermarket within three miles (and its second closest within five miles if its closest was more than one or less than three miles – Category 4), three miles is chosen as the threshold distance in the CSO. Although previous research has documented that ten miles is the farthest distance for rural areas, it was not used for the threshold distance here because ten miles would largely demarcate the MSA into areas that either had access or did not, with no finer discrimination. Three miles is the distance that best differentiates grocery store access across the MSA.

At this point, with some basic information about the MSA revealed and with some justification for the threshold (bandwidth) value for the CSO method provided, analysis shifts to the more sophisticated CSO method that incorporates distance decay, tallies numbers of opportunities within three miles, and is a ratio-level index upon which advanced analysis methods can be used to uncover stronger evidence of spatial correlation between supermarket access and socioeconomic population traits.

Cumulative Spatial Opportunities (CSO) Analysis of Supermarket Access

Figure 3.5 shows the result of the CSO index. Not surprisingly, this map is very similar to Figure 3.4 in overall appearance and pattern, as both maps measure access to the same pool of grocery stores in and around the MSA. Again, the central corridor has higher access and access decreases towards the edges of the metropolitan area, with pockets of higher access existing in some of the suburbs (El Reno, Guthrie, and Norman stand out) where more outlying opportunities exist.

Figure 3.5: Cumulative Spatial Opportunities Scores (3 mile bandwidth)



The similarity of Figures 3.4 and 3.5 is reassuring, because it means that the two methods provide generally similar portraits of accessibility across the study area. If Figures 3.4 and 3.5 were noticeably different, one would suspect that any observed patterns of differential access were simply the result of methodological differences rather than revealing real patterns on the landscape. Although the impacts of spatial autocorrelation must be considered in any inferential analysis, at this point we are reassured that any statistically significant patterns found in subsequent analysis likely represent notable relationships between access and various socioeconomic indicators and not merely underlying artifacts of the method of measuring access.

Figures 3.4 and 3.5 are also noteworthy because they indicate that the portion of Oklahoma City hypothesized to possibly be underserved, the central city and/or downtown area, might not suffer from a grocery gap like occurs in other metropolitan areas in the U.S. This result, combined with other recent research in the Oklahoma City MSA, indicates that Oklahoma City may be rather atypical in terms of access levels to grocery stores, doctors (Brown 2011b), and variations in food prices (Brown 2011a). Oklahoma City's history as a latecomer on the American urban scene and its large footprint (and low population density) both have likely contributed to this pattern.

While it is useful and interesting to situate Oklahoma City in the overall context of U.S. metropolitan areas with respect to these findings, of greater interest is an examination within the MSA to determine if any historically-disadvantaged population groups experience poor access to affordable food. While overall the central city is well-served, nonetheless certain groups might experience poorer access than others, leading to focused efforts to understand and perhaps ameliorate the health challenges faced there.

As noted at the end of the Background section, the presence of autocorrelation will invalidate the results of simple correlation analyses. An initial examination of global levels of spatial autocorrelation will indicate whether these concerns are warranted. A variety of weighting schemes were tested, including first-order rook's contiguity (neighbors share a border of non-zero length), queen's contiguity (neighbors can share zero length (point) borders), k-nearest neighbors, and distance-based methods in which all observations are considered neighbors. For both the k-nearest neighbor and distance method, distances between an observation and its neighbors are computed, and near neighbors have higher weights than farther ones (distance decay). The k-nearest neighbor, rook's, and queen's contiguity measures all produced roughly similar results, so the k-nearest neighbor method is used here because it performs well when the areas (tracts) are of differing sizes (Anselin 2003), as occurs here. A value of eight is used for k, the number of neighbors.

Simple global Moran's I values are computed for each of the socioeconomic variables and the CSO measure; these are shown in Table 3.4 ranked from highest (positive) spatial autocorrelation to lowest. Of note, the expected value of Moran's I is not zero as with Pearson's r but rather is $\frac{-1}{n-1}$ (Getis 2010), which for 333 observations (tracts) produces an expected value close to zero (-0.0030) under a null hypothesis of no spatial autocorrelation. In comparison to this value, all variables are significant to at least the 0.2 percent significance level using a permutations approach (Anselin, Syabri and Kho 2010) with 999 permutations. Hence, all variables exhibit strong positive autocorrelation and simply correlating them with Pearson's r would potentially lead to severe Type I errors when rejecting null hypotheses (Haining 1990).

Table 3.4: Global Univariate Spatial Autocorrelation Statistics

Variable	**Moran's *I***	**Significance (p-value)**
Percent Hispanic	0.7468	< 0.001
CSO	0.6157	< 0.001
Percent with no diploma	0.6099	< 0.001
Percent African-American	0.5386	< 0.001
Percent living in poverty	0.3152	< 0.001
Percent elderly	0.1625	< 0.001
Percent American Indian	0.1246	< 0.001
Percent with no vehicle	0.1129	0.002

Across the MSA, the Hispanic population is the most concentrated, followed by those without high school diplomas and African-Americans. Those living in poverty are moderately clustered, while the elderly, American Indians, and those without vehicles are notably less clustered, though the clustering for these groups is still statistically significant. Finally, reinforcing Figures 3.4 and 3.5 is the level of spatial autocorrelation present in the CSO index; there are definite spatial clusters of areas with both good and poor access to grocery stores across the MSA. Having identified such areas, this analysis turns to looking at who lives in these underserved areas and if this matches expectations.

An extension of the univariate Moran's statistic is the bivariate Moran's *I*, which correlates an observation's value of one variable against the spatial lag (average) of its neighbors' values of a <u>second</u> variable. This approach permits a bivariate examination of the relationship between pairs of variables in the presence of spatial autocorrelation, allowing for meaningful interpretations of the strength and direction of the relationships as well as producing significance values for each observation (tract) that can be mapped and examined. As with the univariate statistics in Table 3.4, a k-nearest neighbors weighting scheme is used with eight neighbors, and significance values are derived based on 999 permutations of the dataset. Table 3.5 summarizes these results.

Table 3.5: Global Bivariate Spatial Autocorrelation Statistics

CSO and Variable	**Moran's *I***	**Significance (p-value)**
Percent Hispanic	0.3764	< 0.001
Percent with no diploma	0.2528	< 0.001
Percent living in poverty	0.1732	< 0.001
Percent with no vehicle	0.1028	0.002
Percent elderly	0.0277	0.118
Percent American Indian	0.0103	0.298
Percent African-American	-0.0959	< 0.001

Notably, percent Hispanic and CSO have the strongest spatial association. Thus, the two variables that individually exhibited the most univariate clustering strongly overlap as measured by the bivariate Moran's *I*. This indicates that the Hispanic population does not experience poor access to grocery stores in aggregate. While perhaps surprising, the Hispanic population, especially in Oklahoma City and many other North American cities, has not followed the same historical patterns of migration and settlement as groups like African-Americans or American Indians. Hispanics are relative latecomers to cities outside the Sunbelt, so any "flight" of retail in past decades had long since happened and Hispanic immigrants arrived to already-changed retail landscapes. Also, the Hispanic designation in the U.S. Census is not a racial identifier, and any person of any racial ancestry can also indicate a Hispanic background, making this group far more heterogeneous in theory if not in reality. Also, the potential bias of omitting smaller food stores and ethnic shops is likely not an issue for this group, as anecdotal and visible evidence of such stores catering to a largely Middle American population abounds in small and large towns across America. An examination of the variety of foods available (and their prices) in such shops would be a useful follow-up study.

The other two positive and significant (though relatively small in magnitude) autocorrelation results with CSO are for the percentage of the population without a high school diploma and the percent living in poverty. All three of the positive and significant variables shown in Table 3.5 overlap; the bivariate Moran's *I* value between the percent Hispanic and the percent without a diploma is nearly 0.63, the value for percent Hispanic and the percent living in poverty is over 0.28, and the value for percent without a diploma and the percent in poverty is 0.31. All three of these values are significant to at least the 0.001 level under 999 permutations. However multicollinear these three variables are, nonetheless they paint a less-bleak picture for inner-city residents than in other American cities because they all positively correlate with areas that have high grocery store accessibility measure (CSO) scores.

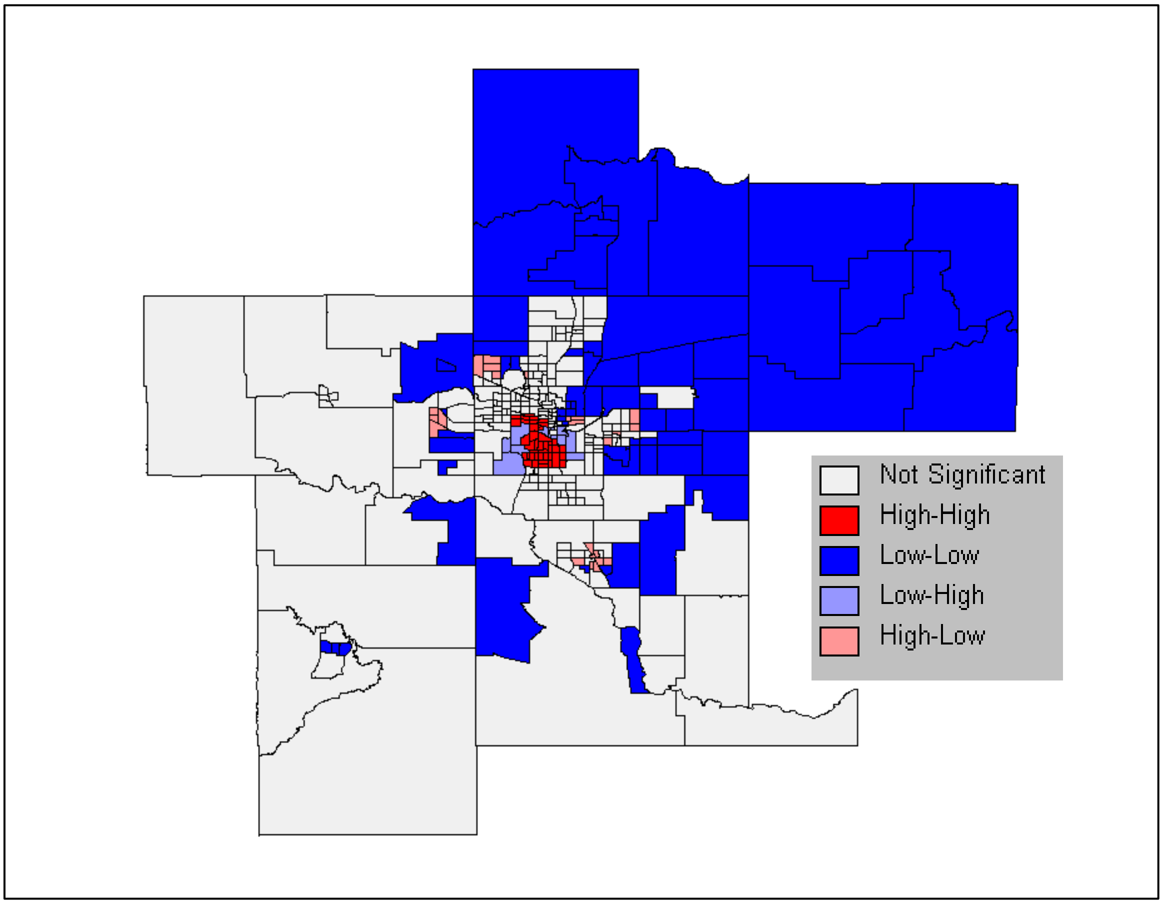
At the other extreme, the value for African-Americans stands out as the only negative autocorrelation detected in this study, either univariate or bivariate. Most importantly, this reveals that Oklahoma City is not entirely unique in terms of equitable access to healthy food for its historically-disadvantaged populations. This is somewhat surprising after reviewing Figures 3.3-3.5, since the African-American population is concentrated just to the east of the downtown area and the largest agglomeration of high CSO scores passes right through the downtown area. However, closer examination of Figure 3.5 reveals that CSO scores drop off rapidly as one moves east of this corridor, exactly where the African-American population of Oklahoma City is concentrated.

These results are useful, informative, and could provide basic information to policy makers, planners, and retailers concerning areas that might warrant attention or extra efforts to attract grocery stores. However, global statistics only tell part of the story.

Most importantly, they do not permit a detailed examination of specific locations where notable problems exist in terms of access for various population groups. As such, another valuable analysis tool is the significance map based on local statistics, showing each tract with a local Moran's I_i value that is significant at the 0.05 level or below. The value of these maps (and local statistics in general) is that they permit the identification and mapping of four types of spatial autocorrelation combinations. Positive spatial autocorrelation can manifest itself as either "high-high" patterns (hot spots) in which significantly larger than expected values of both variables are spatially contiguous or "low-low" patterns (cold spots) where significantly lower than expected values co-locate. Likewise, negative spatial autocorrelation can appear as either "low-high" or "high-low" juxtapositions. For consistency, the relative value of a tract's CSO score is listed before the hyphen and the spatial lag of that tract's neighbors' values of each socioeconomic variable is listed after. Figure 3.6 shows the significance map for the pairing of percent Hispanic and CSO, the strongest bivariate spatial association found.

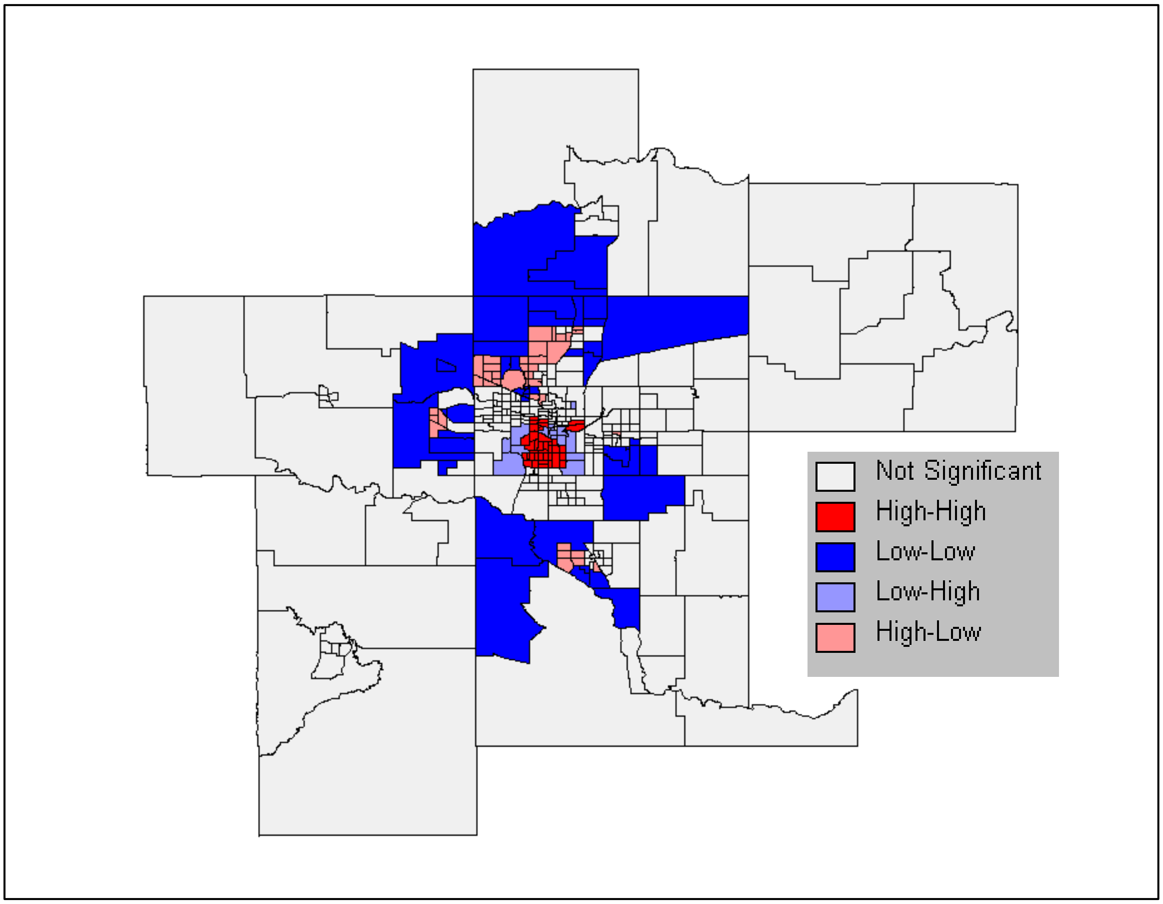
The strong spatial association between these two variables is clearly evident from this map. Both the dark red (high-high) and dark blue (low-low) tracts exhibit positive spatial autocorrelation. The very heavily clustered core of the Hispanic population southwest of downtown overlaps strongly with the tracts that have high CSO scores. Meanwhile, the northwest portion of the MSA has both a very small Hispanic presence and poor access to grocery stores. A few small pockets of negative autocorrelation can also be seen; these are often on the fringes of hot or cold spots where the two variables' values are in transition and some juxtaposition occurs of high values for one variable and low values for the other.

Figure 3.6: Percent Hispanic and CSO Cluster Map



The next highest, and significant, bivariate Moran's *I* value is for the percentage of the adult population (age 25 and over) without a high school diploma. The significance map for this pairing is shown in Figure 3.7. Of note, the hot spot on this map almost perfectly matches that shown on Figure 3.6 because the various socioeconomic characteristics themselves correlate heavily. Thus, locations with large concentrations of Hispanics, poverty, low educational attainment, and poor access to private transportation are all likely to co-locate. However, several negative autocorrelation areas with high access and high education levels (low percentages of persons without diplomas) are quite noticeable. Edmond to the north and Norman to the south both stand out. Edmond has a

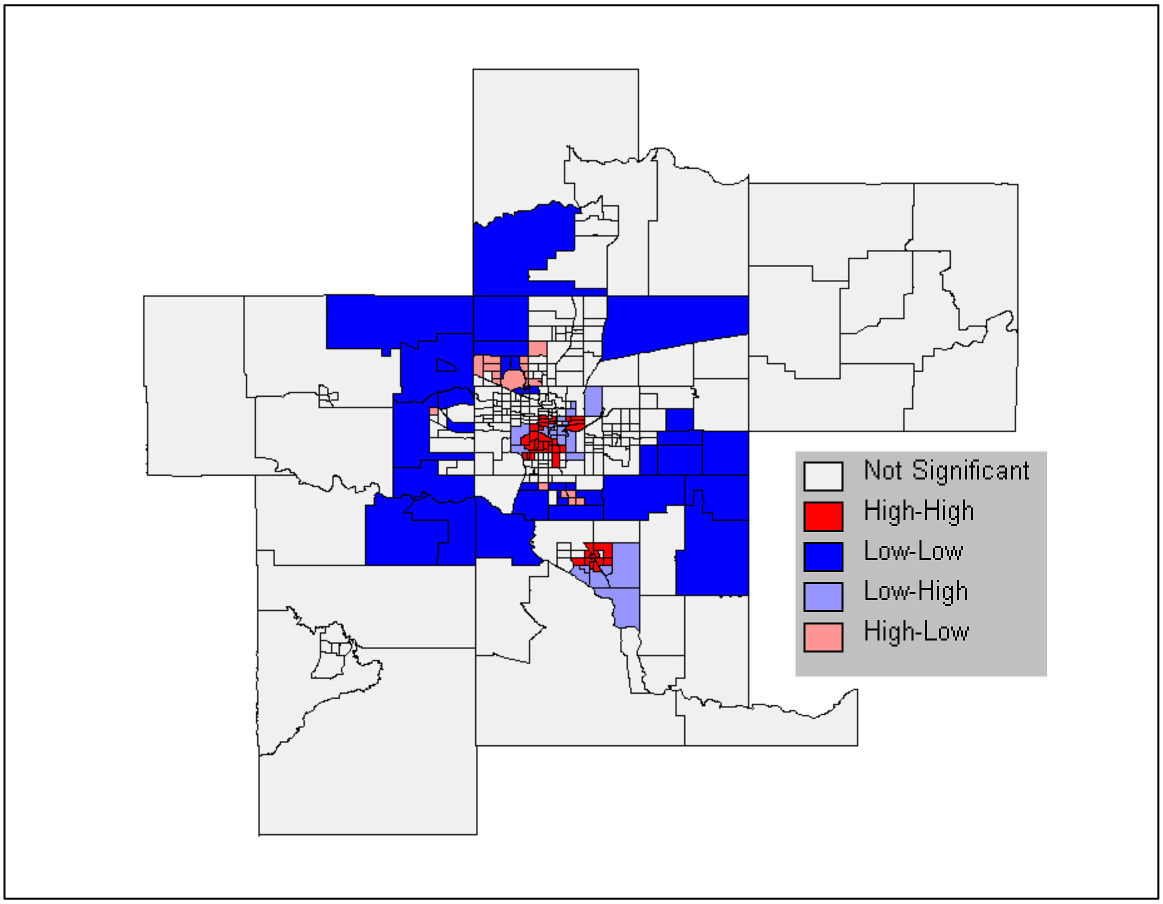
Figure 3.7: Percent with No Diploma and CSO Cluster Map



reputation for being a wealthy suburb, and Norman is home to the University of Oklahoma. The other form of negative autocorrelation noticeably surrounds the hot spot; areas of poor access adjacent to the Hispanic cluster also have high percentages of persons without diplomas. Again, this reveals that the corridor of good grocery store access is quite narrow, and while it runs through the Hispanic cluster of Oklahoma City it misses concentrations of other groups in the MSA.

The final significant positive autocorrelation result is for percentage of persons living in poverty; this significance map is shown in Figure 3.8. Not surprisingly, the Hispanic dominated area southwest of downtown Oklahoma City is apparent here as well

Figure 3.8: Percent Living in Poverty and CSO Cluster Map

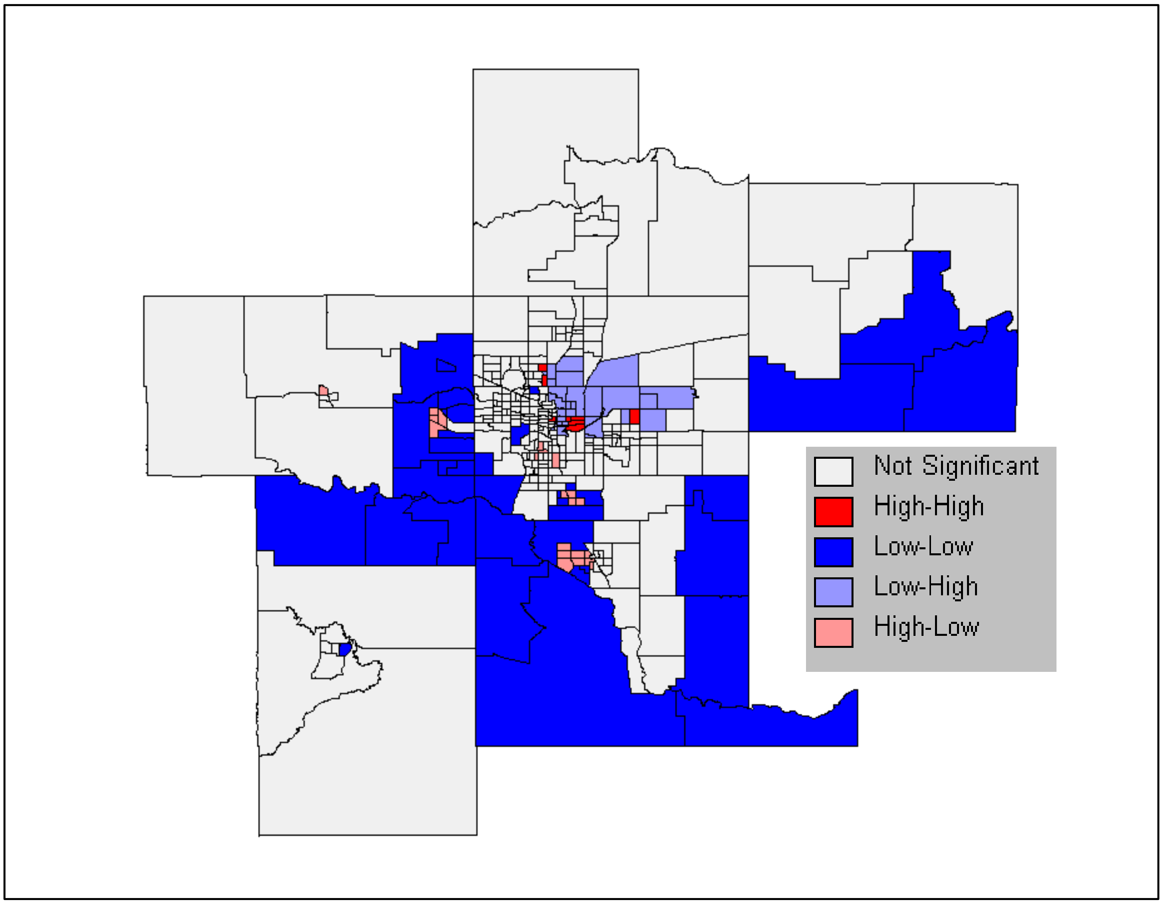


due to the aforementioned links between Hispanic origin, low educational attainment, and poverty. Again, however, this area is congruent with an area evincing good access to grocery stores, resulting in a hot spot. Surrounding this hot spot is a low-high zone of poorer residents who do not enjoy good access to grocery stores, as well as a similar low-high zone to the south around Norman adjacent to a high-high zone. Though seemingly at odds with the discussion relating to Figure 3.7, university towns typically go against the low education-high poverty trend as college students almost by default must have high school diplomas but also typically have very low incomes while in school. This relationship occurs even more strongly in Stillwater, which is a college town with a similar-sized campus population but which is much more isolated in north-central Oklahoma. As a result, Payne County often ranks as one of the worst counties in the state in terms of the percentage of population living in poverty, but is highest in educational attainment per capita.

One other area worth noting is a high-low cluster northwest of the downtown area centered on Lake Hefner (note the almost perfectly circular tract in that area shaded pink). This area has many grocery stores and is a fairly affluent area, resulting in this classification, and while not analyzed is known to be close to the highest concentration of Asian Americans in the metropolitan area. In Oklahoma City, past research (Comer and Skraastad-Jurney 2008) has found a moderately strong spatial association between income and the Asian population.

As noted earlier, the lone result that matched expectations derived from the literature, that African-Americans might experience poor grocery store access, is borne out by the global statistic. However, the Moran's *I* value of -0.09 is not large and is made significant by the large sample size (333 tracts). An examination of the local statistic's pattern in Figure 3.9 reveals that the area causing this statistical result is just east of downtown. This area consists of many tracts with significant low-high local Moran's *I* scores (low access and high percentages of African-Americans), making African-Americans the one clearly disadvantaged group with respect to food shopping options.

Figure 3.9: Percent African-American and CSO Cluster Map



Thus, Oklahoma City resembles many other American cities by virtue of poor access levels for the African-American population, historically the largest minority group in the U.S. This population largely lives just east of the downtown area along Interstate 35, and is an area underserved by grocery stores. Whether grocery retailers never located in the currently underserved area east of downtown or simply left after World War II, is immaterial today, although an historical examination of the history of this area would be useful. Other groups often found to be underserved in other studies – the poor, the elderly, the less educated, and Hispanics – generally enjoy good access in the MSA. On the whole, Oklahoma City is unique in its patterns of grocery store access.

Conclusion

Access to affordable, healthy food for residents of the Oklahoma City MSA is relatively good. Over 80 percent have a supermarket within three miles of their homes. Inner-city residents have the best access compared to rural residents, though not all inner-city residents enjoy equal access levels. Unlike other supermarket access studies, this research found a higher potential of rural residents living in poor access neighborhoods than residents living in the inner city. However, some of these residents could be getting their food from other types of food stores such as convenience stores, dollar stores, or fast food restaurants.

This study has contributed to the literature by examining neighborhood access (via Census tracts) to grocery stores using the Cumulative Spatial Opportunities approach, which improves on simple gravity model or Gaussian distance decay approaches by limiting possible "shopping" options to a fixed distance threshold. Both guidance from the literature and evidence from the Oklahoma City MSA resulted in a choice of three miles for this distance. Using the CSO in conjunction with various socioeconomic indicators designed to represent historically-disadvantaged groups, access is found to be relatively good for the majority of residents across the MSA.

This finding contrasts with many, but not all, past studies of the phenomenon of grocery gaps and food deserts. Bivariate spatial autocorrelation techniques did reveal that African-Americans have poorer access; this group has often been found suffering from poor access to a variety of shopping opportunities in other studies (Hall 1983, Morland et al. 2002, Zenk et al. 2005, Berg and Murdoch 2008). Whether this pattern occurred due to African-Americans moving into an existing grocery gap, or whether the stores left at some point after these neighborhoods were established, would require a detailed historical examination of this area. Such study is beyond the scope of this paper but would be an informative extension to the research presented here.

Other extensions would likewise be interesting. This study only analyzed food retailers that served fresh meat, fresh fruit, and vegetables, and had a wide variety of options. Additional research could analyze locations of convenience stores, dollar stores, ethnic food retailers, and fast food restaurants to determine if this lower quality, less expensive food is more accessible to minorities and low-income residents as well as rural residents.

Overall, this paper employed numerous methods previously documented in the literature, specifically in terms of a process approach, access measures, the use of distance buffers, and network analysis to determine distances between consumers and retail opportunities. However, most past research has limited analysis to simple visual and/or descriptive methods. This paper has employed spatial autocorrelation techniques to more fully explore and explain the grocery retail landscape of the Oklahoma City MSA. Advanced spatial autocorrelation techniques can uncover finer levels of potential poor accessibility for different socioeconomic and demographic groups. Such results can guide policy decisions, urban redevelopment schemes, and even retail marketing with a goal of providing healthy food options for the entire population of the MSA.

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CHAPTER IV

FOOD AVAILABILITY AND AFFORDABILITY IN OKLAHOMA CITY

Abstract

This research investigates food price variability and healthy food availability in the Oklahoma City, Oklahoma Metropolitan Statistical Area (MSA). Previous research has found that healthier food is harder to obtain and is more expensive for socioeconomically imperiled sub-groups, such as minorities and low-income residents. The objective of this paper is to determine whether Oklahoma City residents experience a problem common to many metropolitan areas in which socioeconomically imperiled sub-groups of the population have limited access to healthy, affordable food. This is accomplished by evaluating the prices of a standard basket of goods in supermarkets in these socioeconomically imperiled areas in the metropolitan area based on the Thrifty Food Plan (TFP). Supermarkets are the dominant store type in Oklahoma City as only a handful of independent stores are available to residents. Prices did not vary greatly across the metropolitan area, yet prices varied based on store type. Unlike many American cities, healthy and affordable food is available to socioeconomically imperiled sub-groups in Oklahoma City.

Introduction

The effect of diet on human health has long been recognized. Health inequalities can be caused and perhaps accentuated by food costs and food availability, especially when socioeconomic differences are considered (Boyle et al. 2004). The first documented case of lower income residents paying higher prices was based on a 1963 report regarding durable goods (Caplovitz 1963). Since this publication, researchers from Australia, the United Kingdom, and North America have studied the connections between retail services and variation in cost and access (Alcaly and Klevorick 1971, Ambrose 1979, Chung and Myers 1999, Cummins and Macintyre 1999, 2002, Morland et al. 2002).

For many communities, the perception is that lower income consumers pay more for food. However, most food price literature has found little variation in food price between low-income and high-income areas (Alcaly and Klevorick 1971, MacDonald and Nelson Jr. 1991, Chung and Myers 1999, Cummins and Macintyre 2002, Jetter and Cassady 2006, Latham and Moffat 2007). The lack of a relationship between income and food price has caused researchers to evaluate other factors that influence healthy food consumption. In Glasgow, Scotland, Cummins and Macintyre (2002) found that shop type was most important in determining higher prices. They also reported that when shopping locally, low-income consumers often paid higher prices for goods that are typically only available in smaller stores with limited products such as fresh fruit or dairy products.

Consuming more fruits and vegetables and less fatty foods is known to have positive health effects, but socioeconomic and demographic factors such as income strongly influence the type of food purchased. Consumers with a higher socioeconomic status tend to have a diet that is closer to the healthy recommendations (Fernandez et al. 2000). Additionally, Latham and Moffat (2007) found more price variation in shop type than in neighborhood makeup. Having physical access to food is essential, but food availability and food price also play an important role in diet and overall health.

Food availability will have an impact on selection as well as price. Healthier foods may be unavailable or unaffordable for low-income consumers (Jetter and Cassady 2006). Low-cost foods tend to be of higher caloric value and energy-dense. Eating these energy-dense foods can contribute to a wide variety of health problems, including cancer, osteoporosis, and gallstones (Robertson, Brunner and Sheiham 1999). Obesity, heart disease, and diabetes can be linked to diets that are high in trans fats (Mann 1994). However, diets that are high in fiber and low in saturated fat and sugar can reduce the risk of cancer and heart disease (Steinmetz and Potter 1996). Increased vegetable and fruit consumption is linked to a reduction of many cancers, including stomach, lung, colon, and breast (Steinmetz and Potter 1996, Franceschi et al. 1998, Fernandez et al. 2000).

One state that has a poor record of healthy eating is Oklahoma. The state ranks lowest in the United States when it comes to fruit and vegetable consumption, obesity, and heart disease (Muchmore 2010). Understanding how food prices differ in a targeted area with socioeconomically imperiled groups will provide policy-makers at the local and state levels with information about which consumers, if any, are experiencing price disparities in healthy food. Evaluating the affordability of healthy food for residents will promote a better understanding of how food prices might be related to recurrent health problems and what steps, if any, public agencies, private entities, and the citizenry can take to improve overall health levels of residents.

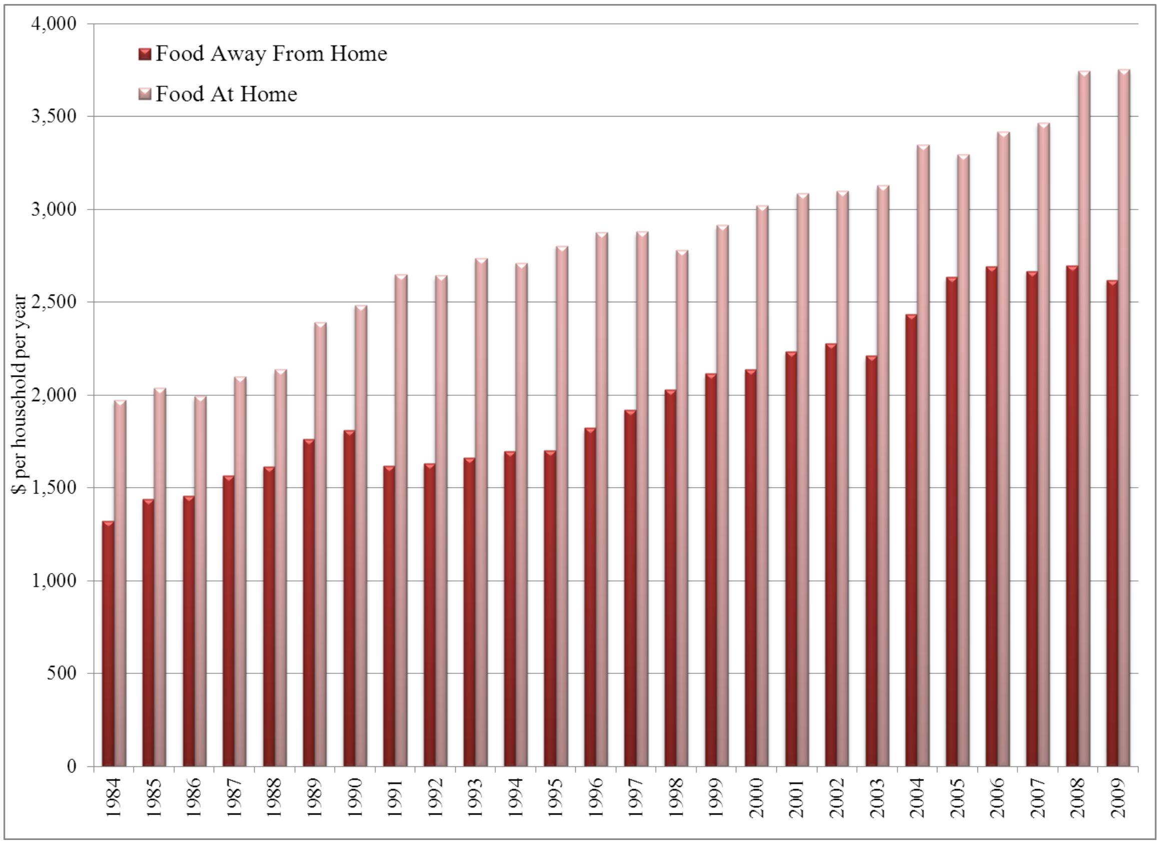
Background

Food Consumption Patterns

Nutritious food consumption, including adequate quantities of fruits and vegetables, is crucial for overall health and can lead to the prevention of conditions related to poor nutrition; examples include obesity, diabetes, heart disease, and some cancers (Steinmetz and Potter 1996, Franceschi et al. 1998, Fernandez et al. 2000, Neal 2006, Sharkey, Horel and Dean 2010). To achieve the recommended five daily servings of fruits and vegetables, the United States Department of Agriculture (USDA) recommends not just fresh fruits and vegetables, but canned, frozen, and even 100 percent juice concentrate (Glanz et al. 1998). However, prices for fresh fruits and vegetables have been on the rise. The Bureau of Labor Statistics (BLS) and the Census Bureau conduct two surveys, the Quarterly Interview Survey (based on five consecutive quarters) and the Diary Survey (based on two consecutive one-week periods), which supply information on what Americans are purchasing through the Consumer Expenditure Survey (CES 2010) and changing consumer patterns.

The CES is beneficial to understanding how American food choices have changed over time. Rather than limiting questions to how much consumers spend on food, the survey asks about specific food purchases, including how much is spent on cereals and breads, meats, dairy products, fruits and vegetables, and even food away from home. As can be seen in Figure 4.1, the overall trend in expenditures is upwards (BLS 2010), though 2008 marked a downward trend in “food away from home” purchases (i.e. restaurants) with a corresponding increase in “food at home” purchases (i.e. groceries bought to prepare meals at home), likely due to the onset of a recession.

Figure 4.1: Annual Consumer Expenditures (Households) on Food (1984-2009)

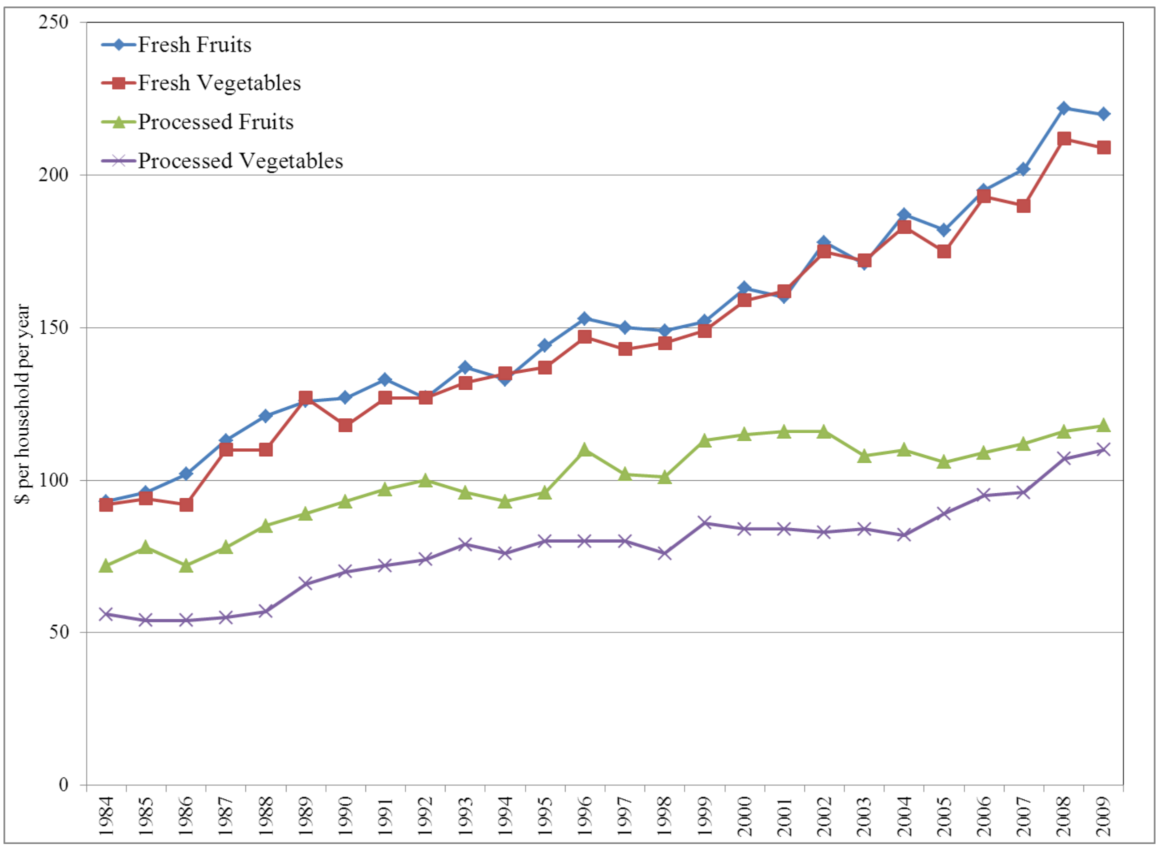


Source: Bureau of Labor Statistics, Consumer Expenditure Survey 2010

An additional feature of the CES is that consumer expenditures on specific food groups are obtained. By examining the changing patterns of expenditures, trends in food consumption are revealed, which can provide valuable information on the growing obesity epidemic in America. Previous research has documented the rise in "food away from home" purchases as a possible reason for the obesity epidemic (Popkin 2010), while others blame low fruit and vegetable consumption as a reason for the epidemic (Drewnowski, Darmon and Briend 2004). Other stuides suggest the problem may be tied to the increase in high fructose corn syrup and other oils that are found in a multitude of food products (Schoonover and Muller 2006). Although the CES does not provide information specifically on purchases of foods using high fructose corn syrup, it does provide consumer expenditures on fruits and vegetables as well as sugars and oils.

Figure 4.2 shows consumer expenditures on fresh fruits and vegetables (BLS 2010). While expenditures on processed fruits and vegetables have remained relatively steady throughout the past twenty-five years, expenditures on fresh fruits and vegetables have steadily increased. Better promotion of the health benefits of canned, frozen, and other types of processed fruits and vegetables as well as information pertaining to their lower cost could lead to an increase in consumer expenditures on these items. This would then lead to better health with more consumers eating the recommended amounts of fruits and vegetables, which could reduce rising obesity rates in the United States.

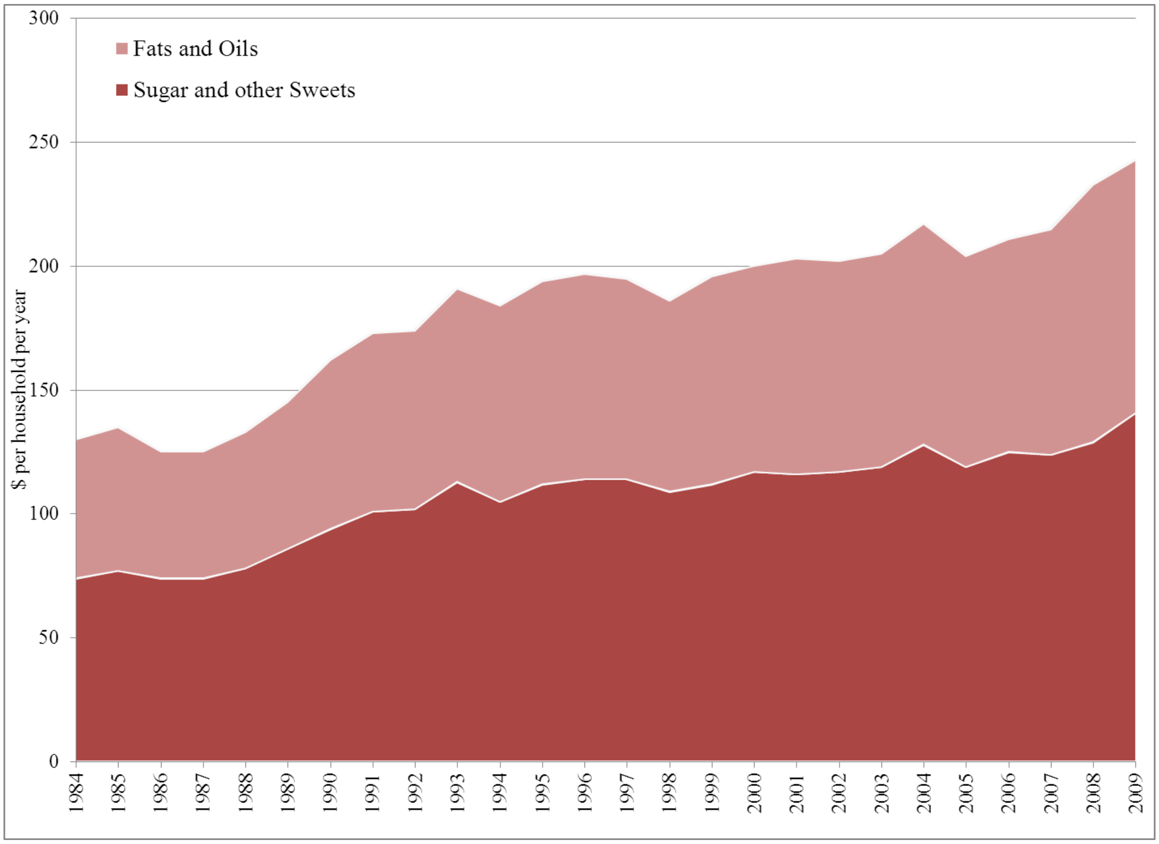
Figure 4.2: Annual Consumer Expenditures on Fruits and Vegetables (1984-2009)



Source: Bureau of Labor Statistics, Consumer Expenditure Survey 2010

Another factor believed to contribute to the rising obesity epidemic is the increase in the amount of sugar consumed in America (Drewnowski, Darmon and Briend 2004). Figure 4.3 shows consumer expenditures on sugars and sweets.

Figure 4.3: Annual Consumer Expenditures on Sugars and Sweets, Fats and Oils (1984-2009)



Source: Bureau of Labor Statistics, Consumer Expenditure Survey 2010

Although not a definitive reason for the rising obesity epidemic, the USDA has recommended that fats and oils be reduced in diets in America, yet one of the problems with fats and oils is that they are heavily present in the cheapest products found in supermarkets (Schoonover and Muller 2006). Though cost influences purchases, taste is the most important, followed by cost, nutrition, convenience, and weight control (Glanz et al. 1998). Additionally, socioeconomic position and demographics play a role in purchasing healthy food. Research shows that women are more likely to consume the recommended servings of fruits and vegetables than men (NFAPP 2001).

Market Basket Studies

The cost of healthy food and how that cost varies across an MSA is an issue for low-income residents due to price differences and food (un)availability across cities (Donkin et al. 1999). While access to healthy food is an additional concern, an understanding about the types of healthy foods available and their cost must also be understood. The local food environment plays a vital role in the types of foods available and choices consumers make regarding food purchases (Connell et al. 2007). Therefore, it is important to understand economic access (affordability) as well as the physical access (location) of food stores. Understanding the food environment as well as food availability could provide insight into health discrepancies (Cummins and Macintyre 2002, Jetter and Cassady 2006, Latham and Moffat 2007).

The food environment has been studied extensively with regard to socioeconomically-disadvantaged areas. Many studies have found the presence of "food deserts" or "grocery gaps" (Hall 1983, Alwitt and Donley 1997, Cummins and Macintyre 1999, Donkin et al. 1999, Piacentini, Hibbert and Al-Dajani 2001, Morland et al. 2002, Shaffer 2002, Wrigley, Warm and Margetts 2003, Connell et al. 2007, Powell et al. 2007, Kwate 2008, Macdonald, Ellaway and Macintyre 2009, Gordon et al. 2011, Walker, Keane and Burke 2010, Eckert and Shetty 2011, Hallett IV and McDermott 2011). Some of these findings have been attributed to spatial and economic restructuring within cities.

During suburbanization, when central cities began losing population, retail firms moved to the periphery and along transportation corridors. Retail voids were created due to declining population densities and lower profits, which hit the supermarkets the hardest because of their limited trade areas. When supermarkets moved to the suburbs, poor mobility (generally inner-city) residents experienced reductions in grocery shopping opportunities (Mayo 1993). This situation means finding healthy food can be problematic and can lead to poor food choices, especially for residents with low incomes.

The majority of the studies on grocery gaps in the United States has found that inner-city residents and minorities have the poorest access to healthy food (Shaffer 2002, Zenk et al. 2005, Berg and Murdoch 2008). Others with limited supermarket accessibility include rural residents, single parents, the unemployed, the elderly, those who are disabled or ill, and those without a car (Westlake 1993, Furey, Strugnell and McIlveen 2001, Sharkey and Horel 2008). This lack of access can cause increases in both travel costs as well as food prices. Lower income residents have less to spend and any type of increase in the cost of needed goods will have severe consequences. High costs can cause low-income consumers to sacrifice necessities such as shelter, clothing, and even healthy food (Shaffer 2002). For example, in the Lower Mississippi Delta region access to supermarkets was limited for low-income residents and those who had inadequate transportation had to shop in smaller food stores with a smaller variety of nutritionally adequate foods (Connell et al. 2007).

However, previous studies on low-income consumers and higher food prices found no price discrimination on the basis of income. In 1966, a comparison of eighteen food items across six metropolitan areas found no relationship between prices and income

(Groom 1966). No significant differences were found when prices were evaluated in two Southern California cities with different income levels on eighty-six foods across forty-nine stores (Marcus 1969). In New York City, prices on thirty-one foods in forty-six neighborhoods were compared and again no difference was found (Alcaly and Klevorick 1971). In the Midwest, fifty-four foods in fourteen stores were compared in Omaha, Nebraska and prices were not statistically significant, yet sometimes the prices were lower in the less affluent areas (Ambrose 1979). In Minneapolis-St. Paul, fifty food items were surveyed in fifty stores and no significant difference was found between low-income and high-income zip codes (Chung and Myers 1999). Expanding information out to 10,000 individuals on nine foods resulted in findings that higher-income consumers paid more for food than lower-income residents (Finke and Chern 1997). In Hamilton, Ontario, a study of sixty-six items in seventeen stores found similar results as mentioned above with no difference in price for low-income residents (Latham and Moffat 2007). In London, prices and healthy food availability were compared when a farmer's market opened, which resulted in an increase in healthy food available to consumers as well as a reduction in overall food costs (Larsen and Gilliland 2009).

These studies provide an optimistic outlook for low-income residents and provide an expectation that no price differences will emerge in this research; however, the study area has significant health problems as well as concentrations of low-income residents and minorities. The study area is defined next and then the data that will be used for the food price analysis are explained. Finally, results describe (a) any food price variation that is occurring in the metropolitan area and (b) if any variation is focused on socioeconomically-disadvantaged groups.

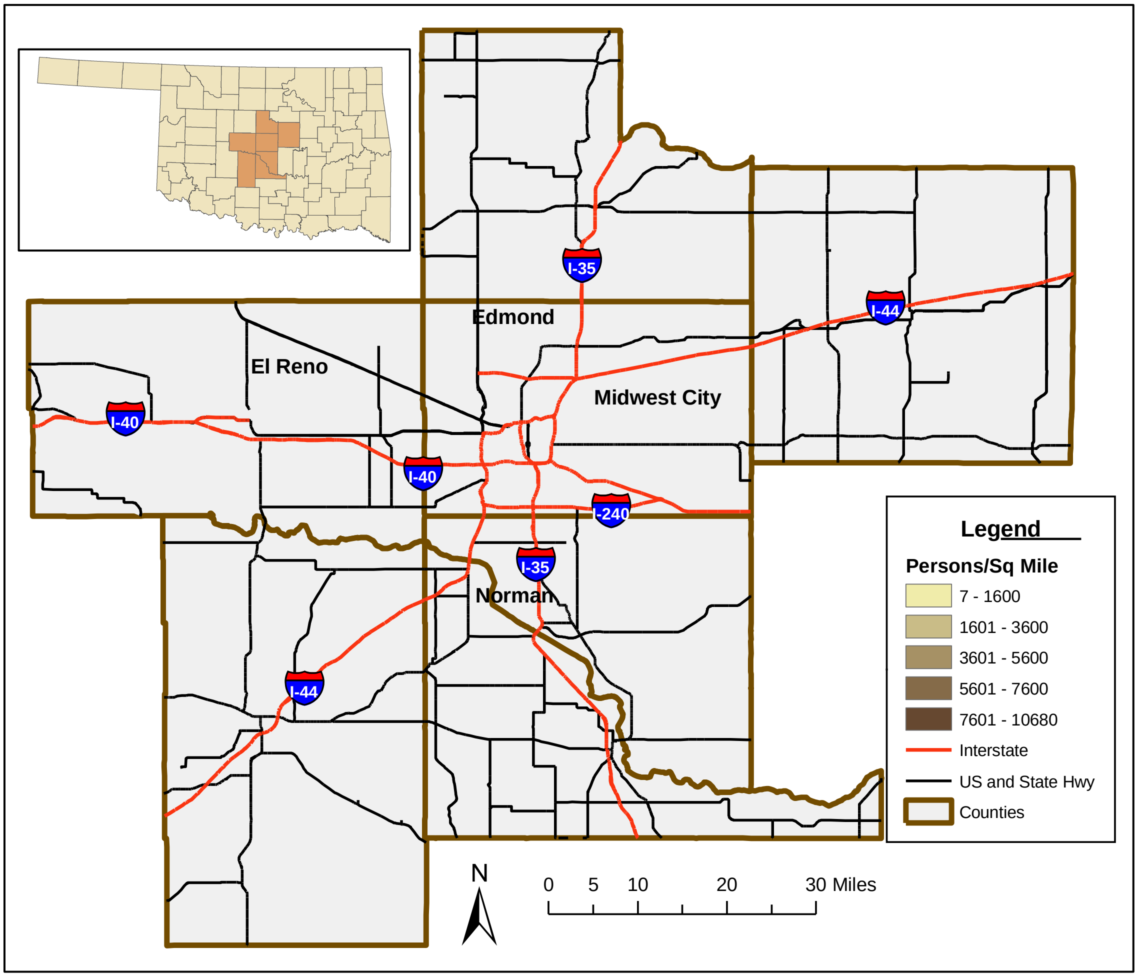
Study Area

Oklahoma in general and Oklahoma City specifically are chosen for study due to their dismal health indicators relating to diet. The state ranks last among all fifty states in the percentage of adults who eat five or more servings of fruits and vegetables daily. Over one-third of the population is overweight, with one-quarter of those obese and a quarter of high school students are overweight or obese. Only one other state has higher deaths due to heart disease. In 2004, Oklahoma ranked worst among states in the percentage of households that go hungry. Additionally, Oklahoma ranks ninth in the amount of population considered poor by Census calculations, which is associated with being overweight (McDermott et al. 2006). Thirty-two of the seventy-seven counties are considered a food desert or grocery gap (Muchmore 2010).

In addition to problems with food accessibility, food affordability and food insecurity are also problems in Oklahoma. Households that are food insecure have difficulty feeding all members of the family, with a third of the households experiencing food insecurity with one or more members of the family going hungry sometime during the year. Almost 200,000 people in Oklahoma households are considered food insecure (McDermott et al. 2006).

Examining the food environment and food pricing for the entire state of Oklahoma is outside the scope of this research. Therefore, this study will examine the largest city in the state to determine if food price variation exists for the socio-economically-disadvantaged groups. The study area is the Oklahoma City Metropolitan Statistical Area (MSA) (Figure 4.4). The MSA has just over 1.3 million people,

Figure 4.4: Oklahoma City MSA with Population Density Mapped



contains the state's largest city, and is made up of seven counties in central Oklahoma (U.S. Census Bureau 2010). It was the fastest growing city in Oklahoma between the 2000 and 2010 Censuses and since 2000 has experienced an increase in minority population, especially with respect to Hispanics (U.S. Census Bureau 2010). The MSA contains a large metropolitan area and suburban communities as well as rural areas with very low population densities. The downtown area is located in the center of Oklahoma City and has relatively light population density. This area contains office buildings, hotels, conference centers, and an entertainment district known as Bricktown. There has been an increase in central city housing construction, but the area still has very little population. As a result, the primary retail establishments are restaurants.

No previous research measuring has examined food price variation in Oklahoma City. In 2006, each county in the state was analyzed for food accessibility and food security (McDermott et al. 2006). Supermarket accessibility was analyzed for Oklahoma City at the neighborhood level and this study found that the majority of the residents had access to a supermarket within three miles (Brown and Comer 2011). Contrary to previous research on “grocery gaps”, the low income and high minority areas had the best access to supermarkets while rural residents had the worst access. Over 80 percent of the population had a supermarket within three miles of Census tract centroids (Brown and Comer 2011).

Store Variation

Throughout the Oklahoma City MSA there is relatively little variation in store type. The overwhelming majority of stores would be considered national chain supermarkets rather than small, independent grocery stores. There is also an abundance of convenience stores and dollar stores, such as *Family Dollar* and *Dollar General*, selling foods. Because of the lack of variation in store type throughout the metropolitan area, this research will focus on price variability among *chain* supermarkets. There are ninety-two supermarkets in the MSA; *Wal-Mart* leads with eighteen Supercenters and ten Neighborhood Markets, *Homeland* has twenty-two stores, *Buy For Less* has thirteen stores, and *Crest* has six stores. There are also three *Super Targets*, fourteen independent grocers, five international grocers, and one *Albertson’s* located in the MSA.

Buy For Less is a local grocery chain that has thirteen stores throughout Oklahoma City. In 2005, the format was changed in some of the stores to cater to the growing Hispanic population. The company's motto is to keep prices low, maintain the highest quality perishables, and provide a large variety of international items (Binkowski 2011). *Crest* is a local grocery chain that has six locations throughout Oklahoma City. The company's motto is "Home of Rock Bottom Prices" and the company strives to provide discount prices, clean stores, and fast and friendly service (Herroz 2011).

Data Sources and Methods

Grocery Store Locations

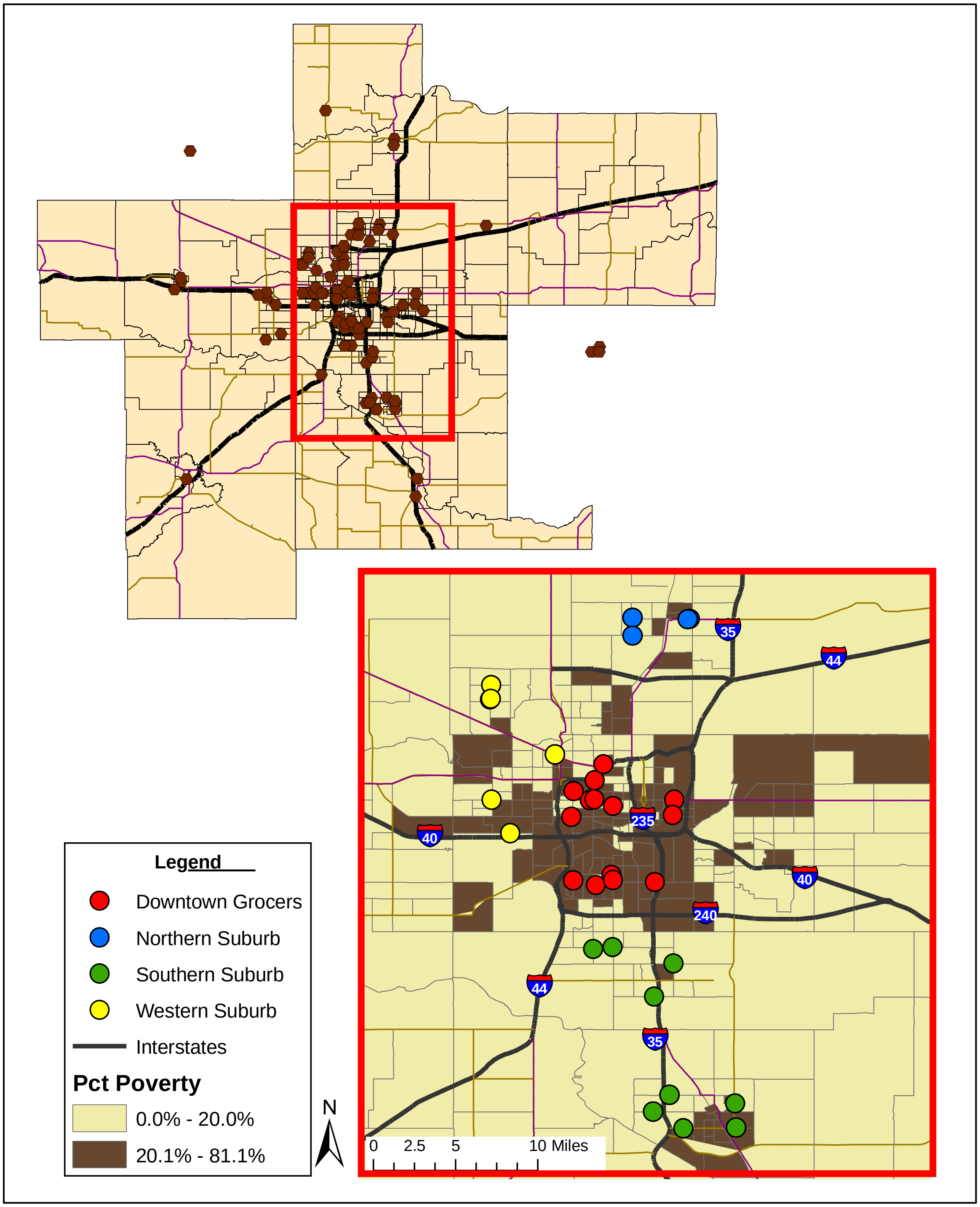
Supermarkets that offer fresh fruits and vegetables, fresh meat, and a wide variety of food stuffs will be used in this study due to their greater presence in the Oklahoma City MSA. This may introduce some bias into the food price data, but as mentioned above the dominant store type is the chain supermarket. The research could be expanded in the future to include convenience stores as well as dollar stores, such as *Dollar General* and *Family Dollar*. However, the majority of consumers purchase their groceries from a supermarket (Berg and Murdoch 2008).

The locations of food retailers was obtained from a retail source and verified with site visits and the telephone directory. Stores were selected in order to compare prices of healthier foods as well as the availability of healthy food for low-income consumers. The designation of low-income consumers was determined by examining Census data at the tract level for percentage of population in poverty. The mean percentage of residents in poverty is slightly lower than 20 percent (U.S. Census Bureau 2009). Areas with a poverty rate greater than 20 percent would be considered *high-risk* for price discrimination and the tracts included in this *high-risk* area are concentrated in the central corridor of the MSA. The poverty rate and minority population statistics were obtained from the 2005-2009 American Community Survey, the most current socioeconomic and demographic dataset available at the tract level (U.S. Census Bureau 2009).

Figure 4.5 shows the overall study area as well as the area under consideration for *high risk* in regards to food price differentiation. There are thirty-three stores that are included in the price analysis in the high-risk area with a wide variety of stores available for pricing. The stores that are within the high risk area are eight *Homeland* stores, six *Buy For Less* locations, six independents, five *Wal-Mart Neighborhood Markets*, four *Wal-Mart Super Centers*, and one *Super Target*. The study area is bracketed to the north and south by Interstate Highways I-44 and I-240, respectively. Additionally I-44 provides the western boundary and the eastern boundary is I-35.

The stores located in this *high risk* area are compared with each other on food availability and food affordability. The *high risk* area prices and availability are compared between downtown and suburban stores in order to identify any differences between low-income areas and more affluent areas. Suburban stores were priced in the northern, western, and southern suburbs. Figure 4.5 also shows the locations of the stores that are categorized as suburban in the Oklahoma City MSA.

Figure 4.5: Oklahoma City MSA and High Risk Area



Consumers who are at high risk for price discrimination are not just those residents in poverty, but minorities and the elderly as well. Past research provides guidance on identifying specific population groups in the study area that are most at risk for price discrimination. Minority populations have been found to have potential price discrimination in previous metropolitan studies and so the percentages of African-Americans, American Indians, and Hispanic populations are included in the study. Additionally, socioeconomic factors such as income and educational attainment have contributed to residents having unequal pricing on products in supermarkets and will be included in this study by using the percentage of residents in poverty and the percentage of adults who lack a high school diploma. Healthy, affordable food is also important throughout our lifespan, so the percentage of population aged sixty-five and older is also analyzed. Finally, transportation access can be a critical factor in determining where an individual can shop, which affects the price of goods. Therefore, the percentage of persons without a personal vehicle is included.

With the elimination of the Census long form in 2010, most socioeconomic data are now collected annually via the American Community Survey (ACS). In order to avoid year-to-year data anomalies this study uses tract-level data from the 5-year ACS based on a sample of approximately two million people nationwide and conducted from January 1, 2005 to December 31, 2009 (U.S. Census Bureau 2009).

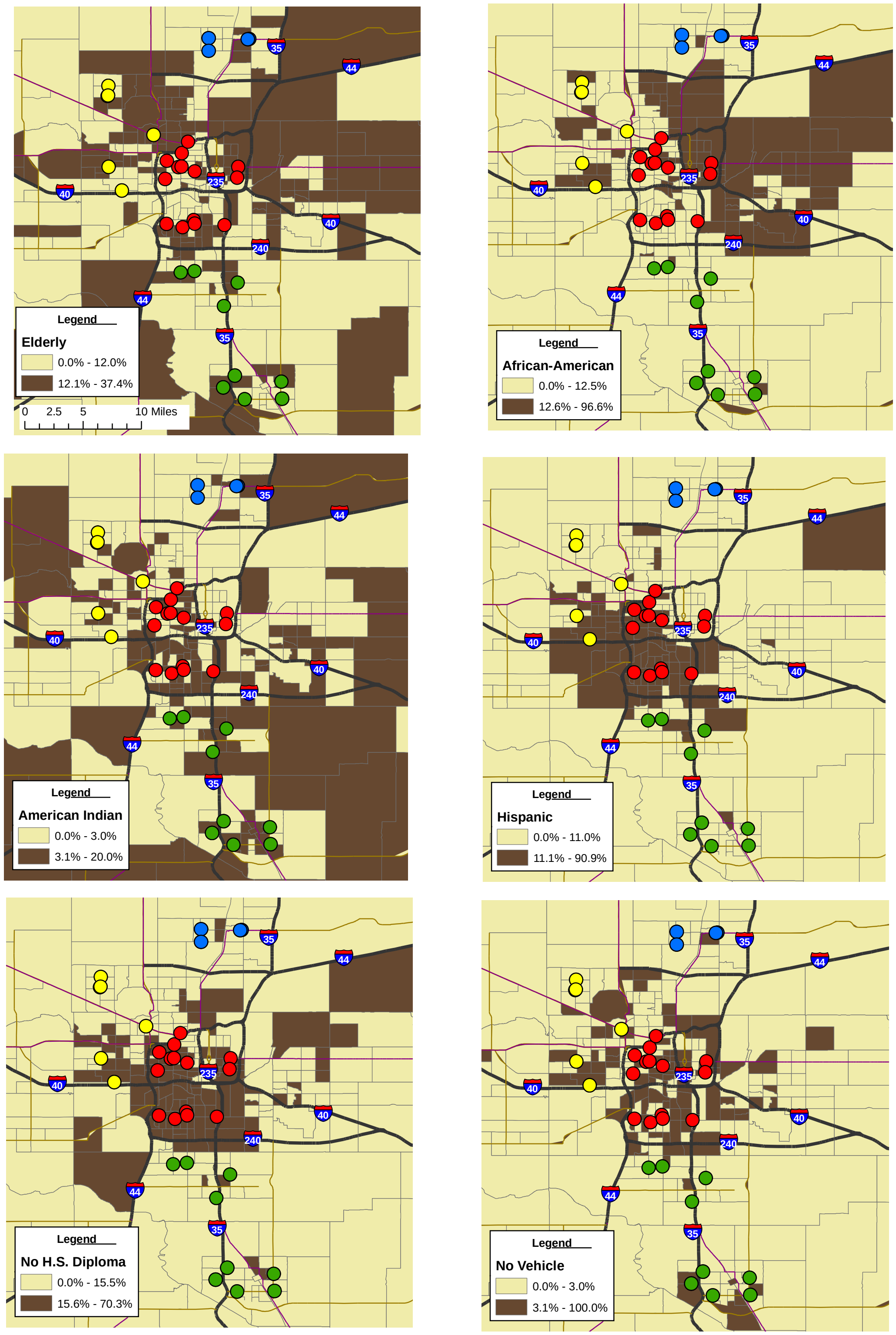
Table 4.1 summarizes the ACS data used in this study with consideration of both the variables of interest and the larger populations from which they are drawn. For example, poverty is based on a subset of the total population for whom poverty is determined, not the entire population since individuals living in group quarters (prisons, mental health facilities, etc.) are excluded. Similarly, educational attainment (high school diploma) is computed for only those residents age twenty-five and older, and car ownership is computed only for those persons age sixteen and older.

Table 4.1: Variables with Table Number and Definition from ACS 5 Year Estimates

Variable of interest	**ACS table**
Percent African-American	B02001 – Race
Percent American Indian	B02001 – Race
Percent Hispanic	B03002 – Hispanic or Latino by Race
Percent with no diploma	B08141 – Sex by Age by Educational Attainment for the Population 25 Years and Older
Percent in poverty	B17001 – Poverty in the Past 12 Months by Sex by Age
Percent elderly	B01001 – Sex by Age
Percent with no vehicle	B08141 – Means of Transportation to Work by Vehicles Available for the Population 16 Years and Older

Figure 4.6 shows the high risk area and the socioeconomic variables. For simpler visualization, each map is shown on a binary scale with tracts above and below the mean. All socioeconomic variables are represented in the high risk area; however, African-Americans, Hispanics, residents in poverty, and those without a high school diploma have the greatest presence in the high risk area. Percent poverty is shown in Figure 4.5 in the inset map of the high risk area. Hispanics are concentrated in the southwest of the downtown area, whereas African-Americans are concentrated to the northeast. Residents without a high school diploma are found in the heart of the city.

Figure 4.6: High Risk Area with Supermarkets and Socioeconomic Variables



Elderly residents are concentrated primarily on the fringe of the high risk area, with some higher concentrations in the downtown. American Indians are scattered throughout the high risk area, yet their density is quite low with an average of 3.3 percent per tract. A similar situation exists for residents without a vehicle. Although the map reveals that there are many tracts where residents do not have a vehicle, this average is under three percent.

Market Basket

The basket of goods priced for this research is based on the Thrifty Food Plan (TFP). The TFP is designed to promote healthy meals at a lower cost, yet still meet nutrition standards. It is the basis for determining benefits for low-income individuals and families using food stamps (Watkins and Anand 2000). Data were collected on forty standard items indicative of foods a family of four would likely purchase for one week of food based on the Thrifty Food Plan (TFP) (Table 4.2).

A standard pricing protocol was followed with only the lowest priced items (including sale items) used in the calculations. For each item, and in each store, the lowest price of each item was recorded for a particular size or weight with consideration about the brand name and whether the item was in stock (Cummins and Macintyre 2002). Stores were surveyed twice, in January 2011 and in May 2011, to account for seasonal variation. Price differentials are compared among all stores and statistical significance testing was carried out using *t*-tests (Cummins and Macintyre 2002, Jetter and Cassady 2006).

Table 4.2: Types and Weights of Food Items, Based on Thrifty Food Plan

Fruits and Vegetables
Apples (6 small)
Bananas (10)
Oranges (small bag)
Carrots (1 lb bag)
Celery (1 lb bag)
Lettuce (head)
Onions (2 lb)
Potatoes (10 lb)

Meat and Meat Alternative
Beef, ground lean 93 (3 lb)
Chicken, thighs (2 lb)
Chicken, skinless, boneless breasts (2 lb)
Tuna fish, chunk, in water (16 oz)
Pork, ground 93 (1 lb)
Turkey, ground 93 (1 lb)
Garbanzo Beans (15 oz)
Kidney Beans (15 oz)
Pinto Beans (15 oz)
Eggs, large (Dozen)

Breads, Cereals, Other Grains
Bagels (6)
Bread, white (1 loaf)
Hamburger Buns (8)
Crackers, low-salt (12 oz)
Oatmeal, quick (18 oz)
Cereal, corn flakes (18 oz)
Flour, enriched (5 lb)
Macaroni, elbow (1 lb)
Rice, enriched (2 lb)

Milk, Cheese, and Additional Items
Evaporated Milk (12 oz)
Milk 1% (2 gal)
Cheese, cheddar (8 oz)
French fries, frozen (32 oz)
Margarine (4 sticks)
Lemonade (1 gal)

Canned Fruit and Vegetables
Applesauce (46 oz)
Peaches (29 oz)
Pears (29 oz)
Green beans (14.5 oz)
Spinach (15 oz)
Peas (14.5 oz)
Tomato Sauce (12 oz)

Adapted from Watkins and Anand (2000) USDA Center for Nutrition Policy and Promotion (TFP)

Results

The analysis of food price variation in Oklahoma City is done in three stages, one based on store type, one based on store location, and finally, one based on food type. However, it is important to note that there were a handful of items from the TFP market basket list that were unavailable for consumers. The item that was missing most often was ground pork, which was unavailable in almost half of the stores. A substitution for ground pork was pork chops, which were available at every store. Ground turkey, garbanzo beans, bagels, and one percent milk were the other items that were unavailable at many stores. Rather than removing the unavailable items from the analysis, missing values were replaced with the average price of the good within the immediate area for the store location analysis and the average price of the good within the same store type for the store type analysis. As would be expected, independent grocery stores were missing more items than the chain supermarkets (Cummins and Macintyre 2002).

Although independent grocery stores were missing some items, these stores did have the second lowest market basket price of the six store types available in the metropolitan area. Table 4.3 shows the price differences among the store types surveyed. *Crest* had the lowest priced items for the market basket. The highest market basket total corresponded to *Super Target*. There were no *Crest* or *Super Target* stores in the area of high risk, but there were multiple *Buy For Less* stores as well as *Homeland* and *Wal-Mart*. *Wal-Mart* stores can also be broken down into *Supercenters* and *Neighborhood Markets*, which have market basket prices of $85.32 for *Supercenters* and $81.05 for the *Neighborhood Markets*. There are two *Supercenters* on the northern and southern edge of the study area and two *Neighborhood Markets* located in the high risk area. Although the high risk area does not include the store with the cheapest basket of goods, there are many reasonably priced options available in the high risk area.

Table 4.3: Price Differences between Supermarkets

Store Type (n)	**Price**
Crest (3)	$76.65
Independents (6)	$77.79
Wal-Mart (9)	$82.94
Buy For Less (6)	$86.07
Homeland (8)	$92.93
Super Target (1)	$97.23

This result is contrary to previous studies since independent grocers had the second cheapest basket of goods. *Crest* is home to "Rock Bottom Prices" and these results show that they do have the lowest prices on this specific basket of goods. The findings above show that there are inexpensive places to purchase food in these high risk areas, but do prices differ between the downtown area and suburban areas?

Table 4.4 shows the price differences between the downtown area and suburban locations. Prices within the downtown area are two cents less than the overall market basket price, which results in the downtown consumers paying the lowest price for this basket of goods at supermarkets by a small margin. The suburban areas also have price differentials, with the southern suburb charging the most for goods and the northern suburb having the lowest market basket cost. A *t*-test was performed on the price difference between the suburban stores and the high risk stores and there was no difference found at the 99% level. This was to be expected due to the small difference in prices between the two areas.

Table 4.4: Price Differences between Suburban and Downtown Area

Location	**Price**
All Stores	$86.07
Downtown Area	$86.05
Suburban Areas	$86.08
North	$82.40
South	$87.53
West	$86.59

These findings are similar to those found in previous research in that there is no difference between low-income areas and the more affluent areas. However, examining only the total cost of the basket of goods does not reveal where the price differences are occurring. Could stores in the high risk area be charging higher prices for specific goods and cheaper prices for others?

Table 4.5 shows the price differences between the groups of foods presented in Table 4.1 and the four locations within the high risk area. The downtown has the lowest prices for fresh fruits and vegetables as well as canned fruits and vegetables. However, it is also shown to have the highest price for items such as milk, cheese, French fries, and lemonade. The southern suburb has the highest prices for meat and meat alternatives as well as canned fruits and vegetables. The western suburb has the highest price for breads, cereals, and other grains, while the northern suburb has the highest price for fresh fruits and vegetables and the lowest prices for breads, cereal, and other grains as well as meat and meat alternatives, and the additional items, like lemonade and frozen French fries.

Table 4.5 also reveals the foods that cost consumers the most money. Meat and meat alternatives are the most expensive food type costing at least double that of other food types. Canned fruits and vegetables were the cheapest food type, costing about half as much as other food types. It is therefore important for consumers to understand that fruits and vegetables are not as expensive. Incorporating canned fruits and vegetables will not significantly increase weekly expenditures and these goods are essential in order to achieve the USDA recommendation of five fruits and vegetable servings per day. Consumers can significantly improve their purchasing power by limiting their meat purchases and increasing the purchase of canned fruits and vegetables.

Table 4.5: Price Differences between Food Types and Areas

Location	**Fruits & Vegetables**	**Breads, Cereal, Grains**	**Meat & Meat Alter-natives**	**Canned Fruits & Vegetables**	**Other: Milk, Cheese**
Downtown	$14.97	$13.76	$33.45	$7.46	$15.72
South	$15.83	$13.75	$34.29	$8.34	$15.70
North	$16.32	$13.35	$30.28	$7.75	$14.77
West	$16.05	$14.74	$32.59	$7.56	$15.68
All Stores	$15.53	$13.88	$33.05	$7.73	$15.60

These results reveal that the Oklahoma City MSA residents living in the downtown area pay the lowest prices for this specific basket of goods. This is similar to previous findings that the poor pay less (Latham and Moffat 2007. However, there can be specific groups that might be charged with higher prices based on socioeconomic status. The maps of these socioeconomic groups were shown earlier in Figure 4.6 and reveal that the area has a mix of populations including minorities, low income residents, and the elderly. Could these groups be experiencing price discrimination on their own? The next set of findings examines stores that are found in tracts with above average socioeconomic variables. For example, the average percentage of African-Americans in Oklahoma City is 12.5 percent. Stores that were included for the African-American pricing were found in those tracts above the mean. ArcGIS 9.3 (ESRI 2009) was used to select stores that intersected the tracts that had above average values for each of the socioeconomic variables. The number of stores per socioeconomic variable was fairly even except for two variables. Only six stores existed in tracts with above average percentages of African-Americans, and only eight stores in tracts with lower than average levels of car ownership. Tracts that were above average in terms of poverty, meanwhile, had the highest number of stores with fourteen.

Table 4.6 presents the price differences of the food types for each socioeconomic variable. Most of the prices are not different from one another. Meat and meat alternative prices have a similar cost across all socioeconomic variables, with just a $1.41 difference between the most and least expensive meats. The largest differences in prices exist with fruits and vegetables, with a $1.64 difference between the most and least expensive fruits and vegetables. Canned fruits and vegetables and additional items were the most similar with $0.73 and $0.43 price differences, respectively. The least expensive basket of goods is found in tracts with high percentages of African-Americans. The most expensive basket of goods was found in tracts with high percentages of residents without a vehicle. This finding is the most troubling because these residents have the least ability to go to supermarkets outside of their neighborhood. Elderly residents had the second highest price for the basket of goods.

The findings presented above reveal very little price discrimination for Oklahoma City MSA residents. In terms of store location and store type, the prices are very similar across all stores and locations. However, when analyzing the pricing alongside socioeconomic variables, residents without a vehicle are paying the highest price for this basket of goods. Minority populations and those with a lower income are paying similar prices as the rest of the study area.

Table 4.6: Price Differences between Food Types and Socioeconomic Variables

Variable	Total Price	Fruits & Vegetables	Breads, Cereal, Grains	Meat & Meat Alter-natives	Canned Fruits & Vegetables	Other: Milk, Cheese
African-American	$84.06	$14.51	$14.16	$31.64	$7.73	$16.03
American Indian	$85.67	$15.61	$14.10	$32.24	$7.91	$15.81
Hispanic	$84.36	$15.14	$13.75	$32.32	$7.39	$15.76
Elderly	$86.93	$16.15	$14.40	$32.85	$7.81	$15.73
No HS Diploma	$84.20	$14.82	$13.97	$32.02	$7.53	$15.87
Poverty	$86.05	$15.28	$13.99	$32.77	$8.01	$16.00
No Vehicle	$87.33	$15.52	$14.87	$32.92	$8.12	$15.91
All Stores	$86.07	$15.53	$13.88	$33.05	$7.73	$15.60

Prices did vary across the items chosen for the market basket, but there were no overwhelmingly high prices found anywhere in the high risk area. Therefore, rather than trying to persuade a new supermarket to come to the downtown area or other areas with socioeconomically-disadvantaged groups, more can be done to educate Oklahoma City MSA residents regarding food price variation. Additional supermarkets would not improve residential health in the MSA. Rather, additional nutritional information regarding how to prepare meals at home, use canned fruits and vegetables, and reduce purchases of higher priced items such as meat would help to improve health. An interesting addition to this study would be to incorporate a food diary survey to understand where consumers are purchasing food and the types of food being purchased.

Conclusion

The choice of foods that are consumed is based on a wide variety of factors including diet, age, gender, cultural traits, education, and income levels (Connell et al. 2007). This research has highlighted the economic availability of food for consumers in the Oklahoma City MSA. Poor and minority locations are often assumed to have the worst accessibility and higher prices for goods. This study has found that poor and minority areas in Oklahoma City actually pay the least for a specific basket of goods compared to the suburban areas of the MSA. The one group that does pay more for goods in the MSA is the residents without a vehicle. However, the majority of the residents at high risk for price discrimination were found to pay the lowest prices for goods.

One of the goals of this study was to try to determine if food affordability may be contributing to the rising health care problems, especially obesity rates in Oklahoma City. One finding of this study is that there is reasonably priced food available for lower income consumers throughout the MSA. However, this study did not make use of food diaries which might have revealed exact food purchases and from what store type(s). An additional limitation of this study is that the focus was only on supermarkets. Convenience stores and dollar stores such as *Family Dollar* are also places where consumers can purchase food. Future research should include these stores in the food environment and information from food diaries to understand where consumers are purchasing groceries and the types of groceries consumers are purchasing.

Previous research has found little price variation in metropolitan areas and this research reaches the same conclusion. However, by detecting modest differences across the MSA both spatially and by chain store, additional information is gleaned about this specific MSA that could guide future efforts to understand differences in food prices and grocery store locations (Brown and Comer 2011) with a goal of achieving greater equity and access to healthy food. One difference between these findings for Oklahoma City and the food price research in other MSAs is the lack of independent or smaller grocery stores. Rather than price variations occurring in the socioeconomically-disadvantaged areas, none existed for this MSA. Additionally, the built environment remained relatively constant across the MSA in terms of grocery store type, which enables consumers of all income levels and racial characteristics to afford and enjoy healthy, nutritional food.

This study paints a positive picture for residents in Oklahoma City. Educational programs that highlight healthy eating and food preparation should be incorporated as well as food price information, such as was found in this study, so consumers can understand how to improve their diet as well as save money while still purchasing healthy food.

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CHAPTER V

CONCLUSION

As the title of the dissertation asks, are Oklahoma City residents OK? In terms of the health statistics for the state, the answer would be no. However, in attempting to identify potential causes for these poor health statistics by examining physician and supermarket access as well as food affordability, the answer would be yes. Rather than finding that specific groups of disadvantaged people are suffering from poor accessibility and high prices, this study found that most of the disadvantaged groups in Oklahoma City enjoy relatively good access to physicians and grocery stores and reasonable food prices. The main findings are that the built environment in terms of supermarkets and physicians are not likely contributing to the poor health of residents.

Overall, Oklahoma City residents enjoy good access to services and uniformly priced goods throughout the MSA. The at-risk area corresponding to poor access is the periphery, which was found in previous research examining both physician and supermarket access. This area in the MSA is predominantly white and has a high percentage of American Indians. The periphery also has high rates of poverty and high numbers of adult residents without a high school diploma. This could be an area for future research through an examination of all aspects of the food environment in the rural area of the MSA as well as the medical care available to these rural residents. One finding that does agree with the literature is poor grocery access for African-Americans and poor physician access for American Indians. However, the Hispanic population had the best access to both physicians and supermarkets, overturning prior expectations.

Chapter 2

Physician accessibility was examined using actual physician locations and tract centroids as a proxy for neighborhoods. The majority of physician access research uses aggregated zip code data for physician location, whereas the use of a smaller study area allowed for actual physician locations to be used. These locations were acquired through a retail source, via the telephone directory, and through site visits. Although this creates some bias by excluding hospital emergency rooms, one of the main objectives of this study was to identify areas within the MSA that had poor access to physicians. Physician access is highest in the central corridor and is lowest in the rural areas. However, traditional statistical methods could not be used due to spatially autocorrelated data. In order to evaluate the relationship between physician access and socioeconomic groups, bivariate autocorrelation statistics were used instead. People who live in the rural areas of the MSA are typically low-income residents with less educational attainment. This socioeconomic group experiences poor access yet it was not significant in terms of spatial autocorrelation. The one group that did experience poor access to physicians was American Indians, who are also found along the MSA periphery. Due to the clustering of medical facilities in the downtown core and the use of a thirty-mile catchment zone, (which is a standard used by DHHS), most of the MSA had good access to physicians.

Chapter 3

Most of the MSA also had good access to supermarkets. This study used two methods to examine accessibility to grocery stores. One was a more descriptive approach that measured the distance to the closest store and the next closest store from each tract centroid. Based on these measurements, three miles was determined to be the distance within which people enjoy good access. This distance threshold was then used in a more robust access index (CSO) that could be mapped and statistically analyzed. However, due to the presence of spatial autocorrelation, traditional statistical methods could not be used. Bivariate autocorrelation statistics were used instead to examine the relationship between supermarket access and socioeconomic groups. Similar to physician access, Hispanics enjoyed the best access to supermarkets and rural areas had the lowest access. A common theme in the literature also played out in Oklahoma City; African-Americans had poor access to supermarkets.

Chapter 4

Although African-Americans have poor access to supermarkets in the Oklahoma City MSA, the price of a basket of goods at available supermarkets was the lowest for this group. Price differences were examined with the majority of the MSA having similar, reasonably-priced products. The basket of goods that were priced was based on the Thrifty Food Plan, which is part of the Food Stamp Program, now known as Supplemental Nutrition Assistance Program (SNAP). The goods that were priced were similar items that a family of four would purchase on a weekly basis. Foods in this plan included fresh fruits and vegetables, canned fruits and vegetables, meat and meat alternatives (such as beans), dairy products, and even frozen French fries. Most of the supermarkets available to consumers in the MSA are chain stores and these stores have a wide variety of prices for this basket of goods. *Super Target* had the most expensive overall price of goods and *Crest* had the lowest.

Rather than only focusing on store chains, the food price article also analyzed area price variations. The downtown location had the lowest price with the southern suburb having the most expensive prices for the basket of goods. Additionally, prices were analyzed based on socioeconomic characteristics. These results revealed that African-Americans had the lowest price for the basket of goods and the residents without a vehicle paid the most. The residents without a vehicle have fewest choices of supermarkets and therefore, this result seems to identify price discrimination for this group. Finally, prices were compared for different food groups, which revealed that meat and meat alternatives incurred the highest costs and canned fruits and vegetables had the lowest costs. Due to the low consumption of fruits and vegetables for Oklahoma City residents, promotion of the nutritional benefit of the canned products could increase health and wellness for residents.

Summary and Future Research

Overall this research examined two key components that are known to aid in maintaining good health: physicians and supermarkets. Other than the rural areas that consist of very low population densities and therefore fewer medical offices and retail establishments, the residents in the urban and suburban areas had good access to these basic needs. Physicians and supermarkets are available and therefore should not contribute heavily to poor health in the MSA. Additionally, an objective was to correlate the accessibility indices and affordability results to socioeconomic data. As mentioned above, rural residents, African-Americans, and American Indians had the worst access to physicians and supermarkets. However, in terms of affordability results, the residents without a vehicle were the only ones who had a higher-priced basket of goods. All other socioeconomic groups had similar prices for items across the downtown and suburban areas. These findings could inform policy decisions that address the health of Oklahoma City residents. Rather than build new doctor's offices and new supermarkets, better information distribution can help residents understand where doctors are located and where they can purchase affordable food. Additionally, an improved educational program that highlights the affordability of healthy food for the MSA could promote better health and reduce the poor health statistics experienced in the MSA as well as the entire state.

However, not all aspects of the built environment were analyzed in this research. Many additional features could have contributed to a better understanding of physician access by including residential insurance rates, hospital discharge data, and patient records. This would have identified how far residents traveled for care. To enhance the food accessibility portion of this study, fast food locations, convenience stores, dollar stores, and community gardens would have revealed all the ways that food is available to consumers. The addition of a food diary would have supported the food access study as well as the food price research by revealing where consumers are shopping and what they are buying. Although these additional features would have enhanced the findings, they were beyond the scope of this study. These extensions represent further avenues for research on this important topic.

This dissertation has provided a case study for potential mechanisms that exist between neighborhood environment and individual health. Rather than finding specific possibilities to explain why poor health exists, this research proposes that physicians and supermarkets are not mechanisms that contribute to the poor health of residents in the Oklahoma City MSA. Additionally, healthy food prices are not as expensive to acquire and also unlikely to be a significant mechanism contributing to the poor health of residents. Just like there are myriad ways to answer the question; Are Oklahoma City residents OK? It seems that there are additional factors that contribute to neighborhood environment and individual health.

VITA

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Thesis: ARE OKLAHOMA CITY RESIDENTS OK? A SOCIO-SPATIAL ANALYSIS OF PHYSICIANS AND SUPERMARKETS VIA ACCESSIBILITY AND AFFORDABILITY

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Scope and Method of Study: The scope of the study examined how the built environment could contribute to individual health by analyzing neighborhoods in the Oklahoma City, Oklahoma Metropolitan Statistical Area (MSA). Due to poor health statistics throughout the state of Oklahoma and Oklahoma City, accessibility to physicians and supermarkets were analyzed as possible mechanisms contributing to poor health in the MSA. Price of healthy food could also be a factor that causes residents to eat cheaper, unhealthy food. Accessibility indices, market basket prices, and bivariate spatial autocorrelation techniques were used to evaluate the built environment's influence on health.

Findings and Conclusions: The findings of the study were that the majority of the MSA had relatively good access to both physicians and supermarkets. Also, prices for the basket of goods were similar across the MSA. The rural areas had the worst access to physicians as well as Native Americans. For supermarket accessibility, rural areas again had poorer access and African-Americans had the worst access. However, in terms of pricing, African-Americans paid the least for this basket of goods and the residents without a vehicle paid the highest. The major conclusion is that physicians and supermarkets are not contributing heavily to the poor health statistics that are found in the Oklahoma City MSA.

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