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Studies on Health, Place, and Education

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Studies on Health, Place, & Education

by

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Dedicated to Sebastian and Savannah.

ABSTRACT OF THE DISSERTATION

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Professor William F. Tate IV, Chair

Good health is positively associated with education outcomes, and likewise higher education-related achievement is positively associated with good health. Similarly, social disadvantage follows a cyclical pattern. It is cumulative; both accruing over the life course and across generations. Moreover, this relationship disproportionately impacts our most vulnerable populations, including both minorities and children living in or near poverty. For example, since the 1990s asthma, the most common chronic illness among youth, has seen the greatest increases in urban environments, and among racial and ethnic minorities in or near poverty. Still, consideration of the interdependence between health, place, and education remains underdeveloped in the literature. Place provides an opportunity to examine the ways in which health and education interact to limit or encourage maximal growth for children, shaping their development and opportunity. This dissertation both affirms prior research examining these relationships and further deepens our understanding of the ways in which health and place interact to impact outcomes for young children. The introductory chapter provides the theoretical framework and a brief review of the literature guiding the studies included in the dissertation. The first study utilizes a large national dataset to examine chronic and recurrent

early childhood health conditions and their impact on reading and math skills of children at kindergarten entry. The final two studies utilize social epidemiological methods which allow for the examination of population level, social-structural factors and health conditions and their impact on developmental and educational outcomes for youth at both regional and local levels. Central to all three studies is the element of geography or place. A final chapter considers the findings of the dissertation as a whole, offering lessons learned and directions for future research.

Chapter 1

Introduction

"I kind of think of it like growing a tree in the backyard. If you tie the tree back and tether it, you can change the shape of that trunk as it grows, and that's sort of what happens with children's lungs for example…For children that grow up in more polluted areas, they don't grow in a sense straight and tall in terms of achieving the maximal growth of their lung health. What they do is tend to be a little stunted; they tend to curve and grow, and our concern is that over the course of years that sort of slight change in the growth trajectory becomes sort of permanent and we have no information that suggests that they jump up and somehow catch up again." Dr. Edward Avol (Center for Investigative Reporting, 2014, 6:15)

Do the places we inhabit tether our most vulnerable youth, altering their growth trajectory, health and education outcomes, and potential in life? This quote by Dr. Edward Avol, a University of Southern California professor of Clinical Preventative Medicine, describing the ways in which polluted environments interact with children with asthma to permanently alter their growth over time suggests they do. Place provides an opportunity to examine how health and education interact to limit or encourage maximal growth for children, thereby shaping their development and opportunity over their life course.

1.1 Introduction

We know that good health is positively associated with education outcomes, and likewise higher educational achievement is positively associated with health outcomes (Alderman, Behrman, Lavy, & Menon, 2001; Basch, 2011a, 2011b; Purnell et al, 2014). Poor health and education outcomes in childhood are associated with poor outcomes in adulthood (Basch, 2011a, Basch, 2011b; Currie, 2005; and Currie & Almond, 2011). Moreover, this connection disproportionately impacts our most vulnerable population, children, and specifically minorities and children in or near poverty. In addition, social disadvantage is both cumulative and place-based, accruing over the life course and across generations (Sharkey, 2013). Still, consideration of the interdependence of health, place, education, and overall well-being remains underdeveloped in the literature. This dissertation seeks to build upon prior work examining these relationships by deepening our understanding of the ways in which health and place interact to impact outcomes for young children, and adds to the evidentiary base in both the fields of public health and education. Further, these correlation studies attempt to inform the development of a future research focused causal pathway through which health and environment impact educational outcomes and the opportunity structure for youth in urban contexts.

Leading to these efforts, my prior work has focused largely on projects examining the links between the built environment, health, and educational outcomes. An initial literature review revealed a dearth in the literature examining this relationship. Specifically missing were robust studies analyzing potential causal relationships as well as larger scale studies examining the impact of place. In prior studies I used geospatial analysis to examine spatial associations between chronic childhood disease (i.e. asthma and mental health disorders) and elements of the built environment. One study in particular found a significant spatial association between asthma and pollution in the St. Louis Metropolitan region[1]. The first study of this dissertation utilizes a large dataset to examine chronic early childhood health conditions and their impact on educational outcomes for individuals nationally. The final two studies utilize social epidemiological methods, which allow for the examination of population-level social-structural factors and health conditions and their impact on developmental and educational outcomes at both a regional and local level. Central to all three studies is the element of geography or place.

1.2 Theoretical Framework[2]

Drawing from both Bronfenbrenner & Morris (1998) and Bronfenbrenner & Evans (2000), the Bioecological Model suggests that human development occurs within the context of the larger ecosystem, and is driven by interactions between individuals and proximal processes, occurring within given contexts and over time (or for short PPCT – Process, Person, Context, Time). The proximal processes are considered the "engines of development" (Bronfenbrenner & Evans, 2000, p.118) and involve the transfer of energy between individuals and their environment, resulting in the development of competence or dysfunction. The Bioecological Model describes how developmental outcomes vary as a function of exposure of individuals and proximal process, their environment or 'context', and time (including both past and present, as well as related historical periods that continue to influence one's context).

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[1] See **Harris, K. M.,** Bell, R., Du, L. (under review). Particulate Matter Emission and the Health, Educational, and Social Characteristics of Residents in the St. Louis Greater Metropolitan Area.

[2] A description of this theoretical framework will be repeated in the initial study.

The Bioecological Model suggests that to be effective the individual interactions and proximal processes must be enduring, over time, and in the immediate environment. These interactions can operate in differing directions and across different characteristics and levels. Person-level individual characteristics include three different categories: demand, resource, and force. Personal characteristics such as age, and gender are demand characteristics. Mental and emotional resources like past experiences, knowledge, and skills, as well as social and material resources like food, housing, health, education, and social capital fall into the category of resource characteristics. Lastly, those characteristics related to drive, motivation, and temperament are force characteristics. These interactions occur within and among four of the five major components of Bronfenbrenner's original Ecosystems Theory (EST), which form the context, or environment (the microsystem, the mesosystem, the exosystem, and the macrosystem). The microsystem is an individual's primary environment, the context in which they spend substantial amounts of time (i.e. home, school, or peer groups). The mesosystem includes interactions between individuals and primary contexts or environments (or microsystems). The exosystem incorporates the influences of contexts that impact individuals, but in which the individual does not themselves operate (i.e. parents job and related stressors, or access or lack of access to resources). Finally, the macrosystem encompasses larger cultural, social, and political phenomena. The macrosystem is the level at which historical periods and policies may further influence individual developmental outcomes.

This dissertation applies the Bioecological Model to the conceptual model in Figure 1.1. This model illustrates the interactions occurring at different levels of one's ecosystem and defines an opportunity structure common for youth in urban contexts and within which individual development occurs. While there is a temporal nature to the model indicating

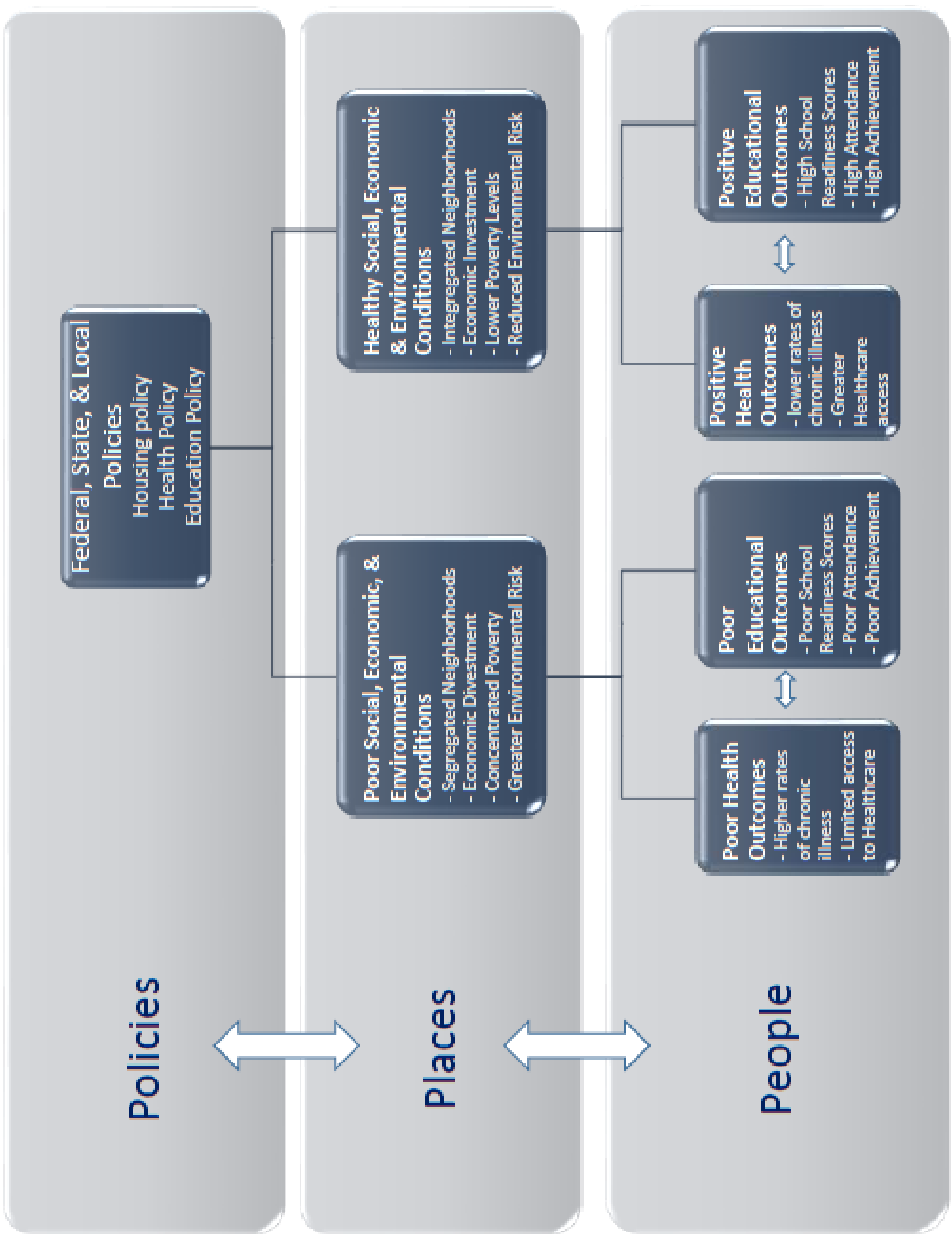

Figure 1.1. Conceptual model demonstrating the relationship between health, place, and education.

causality, causality is not central to its use to inform the studies included in this dissertation. The following studies examine the nature and extent of the relationships in the model at varying levels, and interactions between the levels, but stops short of clearly defining causality.

Beginning at the top, the model suggests that housing, health, and education policy, operating at federal, regional, and local levels ultimately creates places. These places include neighborhoods and communities, comprised of institutions, schools, networks, and families. Places fall broadly into two different categories: 1) those with poor social, economic, and environmental conditions and 2) those with healthy social, economic, and environmental conditions (Anderson & Jones, 2002; Johnson, 2012; Jones, Harris, & Tate, 2015; Rothstein, 2014; Rusk, 2013; Sampson, 2012). Places broadly operate to shape both individual and population level health and educational outcomes, however those with poor conditions often lead to poor individual and population level outcomes while those with healthy or positive conditions lead to positive individual and population level outcomes (Basch, 2011a, 2011b; D. Berliner, 2006; D. C. Berliner, 2009, 2013; Purnell, Camberos, & Fields, 2014; Sampson, 2012).

Central to this conceptual model are the proximal processes outlined in the Bioecological Model, or interactions between individuals and groups and the context or environment which serve to yield these specific outcomes. The model itself is temporal in nature, or more specifically top down incorporating key historical events that serve to shape communities and inequality between communities. The model offers both interactions between levels and interactions within levels. Poor health and education outcomes both reinforce each other and feed back into places to reproduce poor or healthy conditions or characteristics in a more cyclical nature. Further, both individual and population outcomes as well as neighborhood conditions ultimately reinforce policy at the top of the model, as policy makers often respond to their perceptions of the conditions and needs of both place and individuals or groups of individuals. It is important to note, that these perceptions are often guided by the beliefs, values, and experiences of the policy makers themselves. New policy can then either serve to repeat patterns or change places, and thus, outcomes.

Specifically, this model represents federal, regional or state, and local policies which led white middle class families to leave central cities for suburbs (white flight). Together these policies and discriminatory practices led to racially segregated neighborhoods, communities, and institutions (i.e.,., schools) (Jones, Harris, & Tate, 2016). The development of industry focused on central cities and once neighborhoods segregated economic, disinvestment followed. Predominantly African American[3] neighborhoods experience limited banking options and business investments, and those already present tend to leave. Results of this disinvestment can be seen in characteristics common to high poverty-neighborhoods: lower home values and separation from resources, jobs, and those individuals with access to influence policy. Further impacts of this disinvestment are a lower tax base for the neighborhood, which results in less funding for public services such as schools, healthcare resources, and job training (Jones, Harris, & Tate, 2016). Greater environmental risks are present in high-poverty neighborhoods and schools experiencing economic disinvestment. These risks include higher industrial and mobile sources of air pollution, higher density neighborhoods with poor quality living conditions, increased violent crime, and limited access to social, economic, and political resources. Subsequently, these neighborhood characteristics lead to poor health and educational outcomes in the way of increased rates of chronic illness, limited access to healthcare, and for education,

[3] Due to variations in the data sources and preferences of potential publication sites for the studies included in this dissertation, the terms *African American* and *Black* will be used interchangeably throughout the document.

poor school readiness, attendance, and later achievement. Children's development, health, and education are thus shaped by their interactions with their environment and the institutions and resources within the environment (proximal processes). Poor outcomes feed back into disadvantaged places reproducing the conditions and continuing to limit both opportunity and achievement. The impacts of the conditions created are cumulative and cyclical both within and across levels of the model, and subsequently, continue to impact generations of children and families.

1.3 Brief Review of Literature: Chronic Disease

The studies included in this dissertation focus primarily on asthma. Asthma is the most common chronic condition among children. Chronic diseases or conditions are those with a course of disease lasting longer than three months in one year, or requiring hospitalization for a minimum of one month in a given year (Boice, 1998). Perrin (1985) describes a chronic condition as "one that lasts for a substantial period of time or that has sequelae that are debilitating for a long period of time" (p.2). In addition to being persistent and long-lasting, chronic diseases are differentiated from recurrent diseases in that they do not experience relapse or remission. When considering youth outcomes, chronic diseases are important as they have long surpassed acute illnesses as the most pressing health issue facing youth (Hobbs, Perrin, & Ireys, 1985; Boice, 1998).

One in four adolescents in the United States has a chronic illness. Twenty-five percent of adults have two or more chronic illnesses, and approximately 50% have one or more (approximately 133 million people in the U.S.). Chronic conditions account for seven in ten deaths per year, and as much as 86% of healthcare costs in the United States. Given that chronic conditions have become increasingly common among youth, consideration of associated risks youth with chronic illnesses face has become paramount (National Center for Chronic Disease Prevention and Health Promotion, 2016). Studies have shown that youth with chronic illnesses are at greater risk for academic and social-emotional or adjustment problems (Boice, 1998; Krenitsky-Korn, 2011). In addition to being increasingly prevalent, chronic diseases are also preventable and thus a potential point of intervention. A 2008 Trust for America's Health report estimated that investing $10 per person annually in community-based programs in illness prevention and health promotion could save more than $16 billion annually within a period of just five years.

1.4 Organization and Guiding Questions of the Dissertation

As originally mentioned, this dissertation seeks to deepen current conceptions of the nature of the interaction between health and place and how this relationship might impact educational outcomes for young children. Based upon the conceptual model, framework, and review provided, this dissertation begins more broadly and narrows, from a national to a local scale investigating relationships between health, place, and education and using a variety of statistical and spatial methods. The specific questions guiding the work of each study are as follows:

Study 1

The initial study in this dissertation includes the secondary analysis of a nationally representative dataset (Early Childhood Longitudinal Study – Birth Cohort, ECLS-B) to examine the relationship between early childhood health experiences and early academic outcomes. The objective of this initial analysis is to examine the extent to which chronic disease in children, as well as family and neighborhood characteristics, influence developmental outcomes and academic achievement. This study specifically poses the following questions:

1. Do early childhood health experiences (i.e. chronic or recurrent illness, access to health care, etc.) impact children's reading and math skills at kindergarten entry? How do demographic (i.e. race and income) and neighborhood characteristics (i.e. safety, urban location) affect these relationships?
    a. Do chronic or recurrent illnesses such as asthma or ear infections and healthcare access in early childhood impact children's reading and math skills at kindergarten entry?
    b. Does severity of asthma impact children's reading and math skills at kindergarten entry?
2. What is the relationship between children's access to health care (i.e. health insurance coverage, access to care, place for regular care, etc.) and their school readiness?

Study 2

There is a substantial literature base establishing associations between race and income, and health and education outcomes. The second study takes a regional approach, examining the influence of race and other social processes on education outcomes in light of the regional social and political history of the area. In a case study of Missouri, this study explored whether race, poverty, and other in-school factors have a non-stationary relationship with achievement. That is, do these relationships vary geographically across the state of Missouri. Specifically, this analysis seeks to address the following questions:

1. What is the relationship between demographic variables, such as race and poverty, and student achievement? Do these relationships vary geographically across the state of Missouri?
2. What is the relationship between attendance rate and student achievement? Does this relationship vary geographically across the state of Missouri?
3. What is the relationship between discipline and student achievement? Does this relationship vary geographically across the state of Missouri?
4. What is the relationship between district high school completion variables (drop-out rate and graduation rate) and student achievement? Do these relationships vary geographically across the state of Missouri?

Study 3

The final study seeks to examine the associations between health, place, and education on a local level, through a descriptive analysis of neighborhood ecology. Specifically, this study examines potential risk and protective factors impacting the prevalence of chronic childhood illnesses like asthma in St. Louis, Missouri. Further, this analysis seeks to identify hotspots of high and low asthma prevalence, and explore not only the presence of asthma, but also the neighborhood characteristics, healthcare access, and educational outcomes of families in the area, posing the following questions:

1. Is there a spatial relationship between asthma hotspots and neighborhood characteristics (i.e. the presence of public housing, housing quality, or violent crime)?
2. Do families in these ‘hotspots’ have access to healthcare insurance, pediatricians, and controller medications?
3. Is there a spatial relationship between asthma hotspots and school attendance or academic achievement outcomes for elementary age students?

A final chapter considers the findings of the dissertation as a whole, offering lessons learned and directions for future research.

1.5 Acknowledgment of Co-Authorship

The second study included in this dissertation is a co-authored work. As such I have used the Project CRediT (Contributor Roles Taxonomy), led by the Wellcome Trust and Digital Science, as a guide to describe my specific contributions to the manuscript. Project CRediT is an initiative facilitated by CASRAI (Consortia Advancing Standards in Research Administration) and NISO (National Information Standards Organization), designed to assist in the classification of roles performed in the creation of publishable work in the sciences. The goal is to create transparency for collaborations among scholars for published work. In the completion of the second manuscript in this dissertation, I served in a collaborative role in the conceptualization and preparation of the manuscript, and a lead role in data retrieval and analysis (completing all data retrieval, curation, analysis and validation). My responsibilities included formal geospatial analysis of all data, creation of all data tables, and production of all related graphics (figures and tables). Additionally, I participated and served in a collaborative role in original draft preparation, as well as review and editing of this and subsequent drafts and revisions of the entire manuscript. For the manuscript preparation, in addition to figures and tables, I drafted the description of the objectives, methodology, results, and lessons learned sections and performed editing of the introduction and background sections.

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Chapter 2

Health and School Readiness: Examining the Impact of Early Childhood Health Experiences on Early Reading and Math Skills

2.1 Introduction

Social science research provides substantial evidence linking education and health. In adulthood, number of years of education is thought to be the "most important correlate of good health"[4] (Grossman, 2006, p. 600), and among school age children "healthier students are more efficient producers of additions to the stock of knowledge (or human capital) via formal schooling" (Grossman, 2006, p. 591) as they experience fewer absences related to illness. Thus, reducing illness increases opportunities for learning. Further research links poor childhood health to poor later educational outcomes (Alderman et al, 2001, Basch, 2011a, Basch, 2011b; Currie, 2005; and Currie & Almond, 2011). Consistently this body of research demonstrates that home

[4] This is true regardless of how health is measured (mortality rates, morbidity rates, self-evaluation, physiological indicators) or the units of observation (individuals or population).

environment, health, and family are some of the most important predictors of academic outcomes and overall well-being (Campbell et al, 2014; Conti, n.d.; Grossman, 2006; Heckman, 2006; Heckman, 2010).

The link between health and education follows a cyclical pattern beginning before birth and extending throughout the life course. Likewise, this connection disproportionately impacts the most vulnerable population, children, and specifically racial and ethnic minorities and children in or near poverty. Research has consistently shown the impact physical health has on adolescent academic achievement, and school dropout rates (Basch, 2011a, 2011b; Breslau, 2010; Purnell et al, 2014). Adolescents suffering from chronic physical health conditions often miss more days of school, experience less school connectedness, and are at greater risk for participation in risky health behaviors (Basch, 2011a, 2011b). Further, low educational achievement is frequently associated with poor health in adulthood. An intergenerational pattern can be seen when adolescents with poor health and limited academic achievement become adults with poor health outcomes and subsequently have children with poor health (Purnell et al, 2014; Sharkey, 2013).

Frequently research suggests that disadvantaged youth find themselves on the lower end of achievement scales at critical points, such as the third grade (Foster & Miller, 2007; Hernandez, 2012; Lesnick, Goerge, Smithgall, & Gwynne, 2010; McClelland, Acock, & Morrison, 2006; Simms, 2002). What is less clear is the impact of early experiences on academic outcomes for young children. Studies have shown that early life experiences are critical for later development, suggesting that differences in achievement among students may begin before the start of formal schooling and can be explained in part by these early experiences (Gottfried, 2015; Heckman, 2006; McClelland et al, 2007; Shonkoff, 2012). Health is one aspect of early life that influences the cognitive development of youth. Consider, for example, the likelihood that children experiencing chronic conditions such as asthma in their formative years may miss critical learning opportunities and may begin school less prepared and continue at greater risk for lower academic achievement in the early years of formal education. What impact do these early health challenges in young children have on their developmental outcomes and skills before the start of formal schooling? Is it possible that conditions such as chronic illnesses in children cause them to be further behind in school before they begin kindergarten?

A substantial body of research has examined the significance of early childhood education on both cognitive and non-cognitive outcomes such as motivation (Almond & Currie, 2011; Campbell et al, 2014; Heckman, 2006). It is likely that children's early health experiences significantly impact their early educational outcomes and later academic achievement, and potentially before the start of formal education through 'out-of-school' factors such as chronic illness, access to health care, and family and neighborhood characteristics. Results examining the link between early childhood health experiences and early academic outcomes would extend beyond what we know about early childhood education and support consideration of early childhood health experiences in education policy directed at the most vulnerable youth.

2.2 Theoretical Framework

Brofenbrenner (1989) originally described the Ecological Systems Theory (EST), suggesting that human development exists within the context of the larger ecosystem, and influences flow in a bi-directional nature between the five levels or subsystems within the ecosystem. Both Bronfenbrenner & Morris (1998) and Bronfenbrenner & Evans (2000) build upon the original EST with the Bioecological Model, suggesting that human development exists within the context of the larger ecosystem and is a function of interactions between individuals and proximal processes, occurring within given contexts and over time (or for short PPCT – Process, Person, Context, Time). The proximal processes, or "engines of development" (Brofenbrenner & Evans, 2000, p.118) involve "a transfer of energy between the developing human being and the persons, objects, and symbols in the immediate environment" (p.118), and result in the development of competence (knowledge and skills) or dysfunction. The Bioecological Model describes how developmental outcomes vary as a function of exposure of interaction between individuals and proximal process; as well as the specific characteristics of the individuals, their environment or 'context', and the changes occurring over time (including both past and present, as well as related historical periods).

The Bioecological Model suggests that while the individual interactions and proximal processes can operate in either direction, and vary in form, power, and content, to be effective they must be enduring, over time, and in the immediate environment. Person-level individual characteristics are those of demand, resource, and force. Demand characteristics can be described as personal characteristics such as age, gender, etc. Resource characteristics include mental and emotional resources like past experiences, knowledge, and skills, as well as social and material resources like food, housing, health, education, and social capital. Force characteristics include those related to drive, motivation, and temperament. Context, or environment, includes the four major components of Bronfenbrenner's original EST beyond the individual, the microsystem, the mesosystem, the exosystem, and the macrosystem. The microsystem is any environment an individual spends substantial amounts of time in (i.e. home, school, peer groups, etc.), while the mesosystem incorporates interactions between environments or microsystems. The exosystem includes the influences of environments in which the individual does not themselves operate (i.e. parents job and related stressors, access or lack of access to resources, etc.), while the macrosystem incorporates larger cultural, social, and political phenomenon. It is in the macrosystem where historical periods and policies may further influence developmental outcomes. Children's development, health, and education are thus shaped by their interactions with their environment and the institutions and resources within the environment (proximal processes). Ultimately these interactions or relationships are established early and impact outcomes at later stages of development such as kindergarten or school readiness and academic achievement across the life course.

This study examines the link between health and education through this bioecological model and hypothesizes that adverse early childhood health experiences (i.e. chronic illness), family characteristics (i.e. minority status, poverty status), neighborhood characteristics (i.e. neighborhood poverty, crime, and urbanicity), and limited healthcare access negatively impact children's developmental outcomes and kindergarten readiness skills--thus, ultimately impacting their potential long-term educational achievement and adult health.

2.3 Review of Related Literature

2.3.1 Early Childhood Health

Asthma is the most prevalent chronic childhood disease, disproportionately affecting poor, urban, racial and ethnic minority youth, and differences in asthma rates by race cannot be explained by socioeconomic status alone (Eggleston et al, 1999). Further, when controlling for zip code, the relationship between asthma and race or ethnicity disappears (Basch, 2011b, 2011c). The prevalence rate for asthma among African American children (17%) is more than double that of the population (8% for children and adults across the United States) and the decade from 2001- 2009 saw a nearly 50% increase in asthma rates for African American children (http://www.cdc.gov/vitalsigns/Asthma/2009; Akinbami, 2011; Bloom, 2012).

Neighborhood characteristics more common in urban environments, including higher concentrations of pollutants, higher density neighborhoods, limited green space, public and low-income housing, poor housing quality, and violent crime, have also been linked to asthma (Claudio, Stingone, & Godbold, 2006; Corburn, Osleeb, & Porter, 2006; Cummins & Jackson, 2001; Mohai, Kweon, Lee, & Ard, 2011; Patel et al., 2011). Presently, asthma is the primary reason for school absences, and thus, a potential cause for reduced academic achievement among youth (Erwin, Carrico, Glass, & Roberts, 2010; Krenitsky-Korn, 2011; Taras & Potts-Datema, 2005).

Otitis Media (OM) and Otitis Media with Effusion (OME), or more commonly known as ear infections or fluid in the middle ear without an infection, are the most frequently diagnosed illnesses among children in the United States. An estimated $4 billion is spent annually for healthcare costs related to diagnosis and treatment of OM/OME. OME is considered chronic when it persists for longer than 8 weeks, and may result in mild-to-moderate conductive hearing loss from 25db HL to 50db HL, although hearing typically returns to normal when OME resolves. Seventy percent of cases persist beyond 2 weeks, 40% beyond one month, 20% beyond two months, and only 10% beyond three months. For young children this may occur during a critical language-learning period in the first few years of life (Winskel, 2007). Risk factors for OM/OME include child’s age of less than two years, attending daycare, exposure to smoke, and special medical conditions like Down syndrome or craniofacial abnormalities that impact Eustachian tube anatomy.

Literature indicates that prolonged or frequent OM/OME may impact language processing ability during this critical language learning period, resulting in delayed receptive and expressive language skills, attention problems, and difficulty in school (Racanello & McCabe, 2010; J.

Roberts, 2004; J. E. Roberts, 1995; Winskel, 2007). However, whether there are long-term effects from this OM/OME related hearing loss on language and learning or later academic achievement remains unclear and frequently debated. Research by a variety of scholars over three or more decades and encompassing numerous studies has examined these relationships with mixed results (Casby, 2001). A meta-analysis found small effect sizes and concluded that "on average, OME may not be a substantial risk factor for later speech and language development for typically developing children" (Casby, 2001). While "typical" children may be able to recover from early experiences of OME, the lost learning opportunities at such an early age for the most vulnerable populations may have greater impact on language development, early learning, and later readiness for school.

2.3.2 School Readiness

'School readiness' or 'kindergarten readiness' are terms frequently utilized in education research examining early childhood education. Conceptually this term is not consistently defined or operationalized, yet frequently measured to evaluate the effectiveness of specific early childhood programs and to measure children's achievement in the early years. As a concept, school readiness is frequently used as a predictor of later academic achievement and for comparison of children and groups of children based upon their performance. In many circumstances, performance on readiness assessments is used to label and track students and may affect teachers' views of student ability, both of which significantly impact children's academic careers and ultimately may impact their long-term potential (La Paro and Pianta, 2000). School readiness is also frequently used to assess the quality of early childhood programs and their ability to prepare children for kindergarten. Kindergarten readiness is officially assessed in 18 states, and many states in the U.S., as many as one-third or more, require kindergarten screenings. While these assessments are not necessarily consistent in content, those who pass are considered ‘ready’ and those who fail or don’t do as well are often considered to be ‘not ready’ or ‘less ready’ for kindergarten. This, in turn, results in grade retention, tracking, or reduced teacher perceptions of children’s ability.

Several constitutive definitions of ‘school readiness’ exist including some delineated by well-known entities supporting early childhood education programs. Few, if any, researchers have clearly operationalized kindergarten or school readiness, and as such, there is much debate as to which measures most accurately assess various constructs thought to be essential components of ‘school readiness,’ and what those constructs should be. The National Association for the Education of Young Children (NAEYC) suggests,

> School readiness involves more than just children. School readiness, in the broadest sense, is about children, families, early environments, schools, and communities. Children are not innately ‘ready’ or ‘not ready’ for school. Their skills and development are strongly influenced by their families and through their interactions with other people and environments before coming to school…communities are important because readiness for school success is a community responsibility, not just the responsibility of parents and preschool teachers. Communities, for example, should provide high-quality health care and support services for families of young children and work to ensure that all families with young children have access to high-quality care and education” (Maxwell and Clifford, 2004, p. 2).

The National Association of School Psychologists (NASP) notes that “many aspects of children’s lives influence their preparation for formal school learning, including cognitive, social, emotional, and motor development, and, most importantly, early home, parental, and preschool experiences" (Rafoth, 2004, p. 1).

Most relevant research examining school readiness uses measures assessing cognition, general academic knowledge, social-emotional development, behavior, and physical development to determine children's skills before, during, or after their kindergarten year. Studies seem to concur that central to the concept of school readiness are measures of language or literacy skills, mathematical knowledge or numeracy skills, and social development (Bierman et al, 2008). While many researchers consider parental conceptions of what 'school readiness' is, definitions are typically focused on the child and what skills they bring to school (La Paro & Pianta, 2000; Bierman et al, 2008; Brown & Scott-Little, 2003; Britto, 2012). Few studies examine the family, school, and community contributions to school readiness. Also missing are considerations of the larger ecosystem comprising the school, family, and child (Brofenbrenner, 1989).

2.4 Purpose/Objectives

Given that early life experiences are critical for later development, and potentially impact youth before the start of formal schooling, this study seeks to examine the extent to which children's early health experiences influence their school readiness skills. Further, following an ecological model this study hopes to incorporate family and neighborhood characteristics, examining the ways in which these additional factors influence readiness. For the purposes of this study, school readiness is limited to early reading/literacy and math skills at kindergarten entry. Specifically, this study poses the following questions:

2.4.1 Research Questions (RQ)

1. Do early childhood health experiences (i.e. chronic or recurrent illness, access to health care, etc.) impact children's reading and math skills at kindergarten entry? How do demographic (i.e. race and income) and neighborhood characteristics (i.e. safety, urban location) affect these relationships?
    a. Do chronic or recurrent illnesses such as asthma or ear infections and healthcare access in early childhood impact children's reading and math skills kindergarten entry?
    b. Does severity of asthma impact children's reading and math skills at kindergarten entry?
2. What is the relationship between children's access to health care (i.e. health insurance coverage, access to care, place for regular care, etc.) and their school readiness?

2.5 Methodology

2.5.1 The Dataset

The study involves secondary analysis of the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B). The ECLS-B is a longitudinal dataset following a nationally representative sample of approximately 10,700 children born in 2001, from birth through kindergarten entry. The dataset is restricted and housed in the Institute for Education Sciences (IES) in the National Center for Education Statistics (NCES) within the United States Department of Education. The ECLS-B was designed to be descriptive and analytic in nature in four key areas, including children's health status, growth and development over time, transitions to out-of-home programs and schools, and school readiness.

The ECLS-B used a clustered list frame sampling design, with stratified random two-stage sampling. Most children were randomly selected from births registered in the National Center for Health Statistics Vital Statistics system in 96 core primary sampling units (PSUs) (contiguous counties and county groups) of infants born in 2001. An additional sample of 18 PSUs with a higher proportion of American Indian/Alaska Native births were selected to accommodate the oversampling of these groups. PSUs were stratified by census region, metropolitan statistical area (MSA) status, racial/ethnic minority status (high or low), median income (high or low), and size. Birth certificates of children from a variety of racial/ethnic/socioeconomic backgrounds were then sampled from the PSUs with oversampling of specific racial/ethnic groups (i.e. Asian/Pacific Islanders, American Indian/Alaskan Natives), twins, and babies born with low birth weight (LBW, 1500-2500 grams at birth) or very low birth weights (VLBW, less than 1500 grams). All children in the study were born in 2001 and followed through kindergarten entry (which was either 2006 or 2007 for all children in the study). Data was collected on the full sample for four rounds: at 9 months of age (2001-2002), 2 years of age (2003-2004), preschool age (2005-2006), and at the year of expected kindergarten entry (Fall 2006). There was a fifth round of data collection for those children who repeated kindergarten or entered kindergarten a year later (Fall 2007). Data collection activities at all rounds included both direct assessment of children's skills and parent interviews (both computer-assisted and direct interviews). Additionally, child-care providers were interviewed or surveyed beginning at 2 years of age, and kindergarten teachers provided information regarding both the children and school/classroom settings. Child-care providers for before- and after-care settings for kindergarteners were also surveyed, as were center directors for preschools. A subset of the full sample was observed in their child-care settings for the 2-year and preschool rounds of data collection as well.

The content of the ECLS-B dataset makes it ideal for an analysis such as this. In addition to the developmental and academic measures examined, data collection activities captured more robust health measures for children beginning at 9 months of age for all participants. The ECLS-B includes a large variety of health measures and considerable detail on several health outcomes (i.e., frequency of illness, medications or treatment used, etc.). Further, interviews with both resident and non-resident parents and other caregivers provides a more complete picture of children's early experiences and allows for the inclusion of variables specific to family and neighborhood characteristics. The longitudinal nature of this dataset with 5 rounds of data collection allows for the evaluation of temporal relationships between documented early childhood experiences and developmental or academic outcomes assessed across multiple rounds of data collection.

2.5.2 Variables

The research questions posed here are temporal in nature, and thus the element of time must be considered in variable selection. All variables included in this analysis were obtained either through the parent interview, direct child assessments, or demographic information obtained from parents or birth certificates. Dependent variables included those representing school readiness and were obtained from the direct child assessments in the fourth round of data collection measuring skills at kindergarten entry. Data representing each explanatory variable were not necessarily collected at each round, so selection of specific variables and rounds of data to include was dependent both upon data availability and round of collection (at or before round four). Independent variables representing the construct of 'early childhood health experiences' were derived from individual survey items administered to parents across each of the first four rounds of data collection and measuring experiences occurring prior to assessment at kindergarten entry. Covariates for all models, such as race, and child/family poverty status were determined by parental responses to survey items and birth certificate information. Neighborhood characteristics included indicator composite variables in the dataset as well as those derived from parent interview questions[5].

Early Childhood Health Experiences. Independent variables representing early childhood health experiences included those measuring diagnosis of asthma, presence of ear infections, severity of asthma, healthcare access, and place for regular medical care. Diagnosis of asthma was a variable, '*asthma*,' created to represent whether a child has ever had asthma. This variable was created from variables derived from a question in the parent interview asking "since our last interview in {time frame}, has a doctor, nurse, or other medical professional ever told you that [child/twin] has…asthma?" across the first four rounds of data collection. Dummy coding was used to make 'asthma' = '1' for "yes" if parents answered "yes" to that question in any of the first four rounds of data collection, and 'asthma' = '0' for "no" if parents answered "no" to that question in all four rounds of data collection. A similar variable, '*ear infection*' representing whether a child had ever had an ear infection was created from variables derived from a question in the parent interview asking "since our last interview in {time frame}, has a doctor, nurse, or other medical professional ever told you that [child/twin] has…an ear infection?" across the first four rounds of data collection. Dummy coding was similarly set to make 'ear infection' = '1' for

[5] See Appendix A for list of variables. Due to the restricted nature of the dataset, actual variable names are suppressed.

"yes" if parents answered "yes" to that question in any of the first four rounds of data collection, and '0' for "no" if they answered "no" to that question across all four rounds of data collection.

Severity of asthma was defined by four variables representing a child's need to take a medication to treat asthma, their need to take steroids to treat asthma, need for hospitalization, and the number of asthma attacks. '*Asthma Rx*' was a variable representing the need to take a medication to treat asthma in the third or fourth rounds of data collection and derived from a parent interview question asking "why does [child/twin] have to take this medicine? Is it for…asthma?" '*Steroid*' was a variable representing the need to take a steroid to treat asthma in the first through fourth rounds of data collection and derived from a parent interview question asking "how was [child's/twin's] most recent episode of asthma treated by your doctor, nurse, or other medical professional? Steroids/Anti-Inflammatories?" '*Hospitalization*' was a variable representing the need for treatment at a hospital due to asthma in the first through fourth rounds of data collection and derived from a parent interview question asking "since our last interview in {time frame}, has [child/twin] been taken to an emergency room or hospitalized for at least one night because of asthma?" Similar dummy coding patterns were used for the 'steroid,' 'asthma Rx,' and 'hospitalization' variables created, setting '1' to "yes" for affirmative responses to the specific parent interview question at any round, and '0' for 'no' indicating "no" responses across all relevant rounds. A final continuous severity variable for 'number of asthma attacks' from age two to kindergarten entry was created by summing the total number of asthma attacks (as reported in response to a parent interview question posed in rounds three and four, asking "since our last interview in {time frame}, how many times has a doctor, nurse, or other medical professional told you that [child/twin] had an asthma attack?").

As part of the construct of early childhood health experiences healthcare access was measured both by health insurance coverage and ability to access healthcare. The variable for '*health insurance coverage*' was derived from a parent interview from the third round of data collection asking "Is the [child/twin] covered by any kind of health insurance or some other kind of health care plan like those on this list?" Ability to access healthcare was measured by the '*no access to care*' variable, which was a variable measuring the child's inability to access care at a time they needed it across the first four rounds of data collection. This variable was derived from a parent interview question asking "since our last interview in {time frame}, was there ever a time you needed healthcare but could not obtain in?" across the first four rounds of data collection. Dummy coding set 'no access to care' to '1' for "yes" if parents responded "yes" to this question in any of the first four rounds of data collection, and '0' for "no" if they responded "no" in all four rounds of data collection. In addition to the 'health insurance coverage' and 'no access to healthcare' variables an additional continuous variable measuring time without health insurance coverage, '*time without insurance*,' was created from responses to a parent interview question asking "about how many months was the [child/twin] without health insurance or healthcare coverage?" across the first through the fourth rounds of data collection.

Place for regular medical care was measured by a series of five variables created from a parent interview question asked in the fourth round of data collection, "where do you usually go for routine medical care?" Possible responses were 'clinic or health center,' 'Doctors office or HMO,' 'hospital emergency room,' 'hospital outpatient department,' 'some other place,' and 'does not go to one place most often.' Dummy variables were created for '*clinic or health center*,' '*Doctors office or HMO*,' and '*hospital outpatient department*.' Variables were created for '*emergency room'* (uses emergency room for routine care) and '*not one place'* (not one place for routine care) utilizing responses to this same parent interview question across the first through the fourth rounds of data collection. Similar to prior variables, dummy coding patterns were used setting the variables to '1' if in any round of data parents reported their usual place for routine care was an 'hospital emergency room' or 'not one place,' and setting the variables to '0' if parents did not select this option for all four rounds of data collection.

School Readiness. Cognitive assessments used within the ECLS-B include the Bayley Short Form-Research Edition (BSF-R) Mental utilized in the first and second rounds of data collection (given to children at approximately nine months and two years of age), and the ECLS-B Cognitive Assessment Battery which assesses 'Early Reading' (English language skills' and 'emergent literacy skills'), 'Mathematics,' and 'Color Knowledge' utilized in the third and fourth rounds of data collection (given to children in preschool and at kindergarten entry). For the purposes of this analysis school readiness was defined to include 'early reading' and 'math.' Item Response Theory (IRT) modeling was used to estimate scale scores for the 'early reading' and 'math' assessments. IRT scores most accurately represent 'true scores' and are the best measure of overall scores. They are useful for both cross-sectional analysis and longitudinal analyses assessing skills at a single point in time.[6] For this reason, reading and math IRT scores at kindergarten entry (for the fourth round of data collection) were utilized as dependent variables for all research questions (Choosing Scores, n.d.).

Demographic Characteristics. Demographic characteristics included race/ethnicity and poverty status. Race/ethnicity was obtained from children's birth certificates in the first round of

[6] When used in longitudinal analyses, they should not be used to assess gains over time unless cases have a similar initial status, as skills assessed over time change. For these purposes, scores at one point in time are being assessed, and thus, the IRT score is indicative of a 'true score.'

data collection, and two dummy variables representing child race as '*Black'* and '*Hispanic*' were created. Poverty status was defined by two separate variables '*poverty*' and '*near-poverty*.' 'Poverty' was a variable measuring whether family's income was below the federal poverty threshold at any time between the child's birth and the fourth round of data collection. 'Near-poverty' was a variable measuring whether a family's income was below 185% of the poverty threshold at any time between the child's birth and the fourth round of data collection. Both 'poverty' and 'near-poverty' were based on composite variables contained in the dataset (each comprised of four variables related to income, and based on the 2006/2007 census-defined poverty threshold). The 'poverty' variable was a dummy variable equal to '1' if the family's poverty status was equal to '1' indicating "below poverty threshold," and equal to '0' if the family's poverty status was equal to '0' (for "at or above poverty threshold") for all 4 rounds of data collection. The 'near-poverty' variable was a dummy variable created in the same way but based upon responses to the variable representing 185% of the poverty threshold.

Neighborhood Characteristics. Neighborhood characteristics included household zip code and urban location, neighborhood safety, and violent crime. Household urban location was an indicator composite variable obtained during original data collection by merging the zip codes with United States Census (US Census) data for 'urbanicity.' Urban location was measured as 'urban, inside UA' (urbanized area), 'urban inside UC' (urban cluster), or 'rural.' Based upon 2000 US Census definitions for 'Urban and Rural Classifications' and 'Urbanized Area and Urban Cluster Definitions[7],' a new variable was dummy coded for household '*urban location*'

[7] 'Urbanized areas' were defined by the 2000 US Census as "a densely settled core of census block groups and census blocks that meet minimum population density requirements, along with adjacent densely settled surrounding census blocks that together encompass a population of at least 50,000 people, at least 35,000 of whom live in an area that is not part of a military installation" (US Census Federal Register, 2001, pg. 17018). 'Urban clusters' were

where ‘1’= ‘urban inside UA’ and ‘0’ = ‘urban inside UC’ or ‘rural.’ Additional neighborhood characteristic variables included ‘*safe neighborhood*’ and ‘*witnessed violence*.’ Both variables were derived from the parent interview. ‘Safe neighborhood’ was a dummy variable created from a survey question in the third round of data collection asking parents “do you consider your neighborhood very safe from crime, fairly safe, fairly unsafe, or very unsafe?” Dummy coding identified ‘very safe’ and ‘fairly safe’ responses as ‘safe’ (= 1) and ‘fairly unsafe’ and ‘very unsafe’ as ‘unsafe’ (= 0). ‘Witnessed violence’ was a dummy variable created from a survey question in round 4 asking parents “In the last year, (has/have) your (child/children) been witness to a violent act within the neighborhood or home? By violent act, we mean physical fighting, destruction of property, or other kinds of violence” (yes = 1, no = 0). This question was only asked in the fourth round of data collection.

Weight Variable. Given that the latest round of data used in the analysis was collected in round four, the fourth round full sample weight adjusted for non-response to the parent interview was used for these analyses. For the fourth round of data collection only, non-response rates for both the parent interview and child assessment were similar enough that only one weight value was created. The ECLS-B manual encourages use of this weight for analysis including data from both parent interview responses and direct child assessment responses. To account for the complex stratified sampling design, weights must be adjusted to correct standard errors and account for potential underestimation of variance estimates. This is typically done through

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defined as those that meet minimum population density requirements but together with surrounding census blocks include a population of less than 50,000 (but more than 2,500) or more than 50,000 if less than 35,000 do not live in military installations (US Census Federal Register, 2001, pg. 17018). Where ‘densely settled core’ is described to include “one or more contiguous census block groups that have a total land area less than or equal to 2 square miles and a population density of at least 1,000 people per square mile” or with an overall “population density of at least 500 people per square mile, and that are contiguous with the census block groups and census blocks” meeting the initial standard (US Census Federal Register, 2001, pg. 17018). ‘Rural’ is then defined as “all territory, population, and housing units located outside of UAs and UCs.”

Paired Jackknife Replication or Taylor Series Replication methods, which are the preferred methods. Due to limitations in the statistical software procedures used in this analysis these methods were unavailable. For this reason, approximation method was used (Snow, 2009; Tourangeau, 2015). Weights were adjusted by dividing the full sample weights by the median design effect (DEFF) for this weight variable. The DEFF is the ratio of the variance estimate for the sample design (in this case a stratified clustered sampling design) to the variance estimate that would have been obtained if the sample was instead a simple random sample of the same size (Snow, 2009). This method provides reasonable standard error estimates close to those obtained through Jackknife methods, however the degree to which they may vary is dependent upon types of variables and weights used (Snow, 2009; Tourangeau, 2015).

2.5.3 Analytic Approach

The clustered or nested nature of the dataset lends itself to a multi-level analysis and allows for the modeling of variables at multiple levels (individual and neighborhood for our purposes), as well as examination of within neighborhood effects. This structure allows for the analysis of our school readiness outcome variables as well as for an examination of the impact of early childhood health experiences and neighborhoods on these outcomes. Further use of multi-level modeling accounts for the likelihood that individuals within clusters are more alike, which violates the independence of observations assumption of traditional regression analysis. This study utilized 2-level multi-level models to examine the relationship between the variables of interest and the variation within and between neighborhoods.

The GLIMMIX procedure for generalized linear mixed models in SAS/STAT®[8] 9.2 software was utilized for all data analysis. Other procedures within SAS/STAT 9.2 software can also be used to analyze multi-level models, however this procedure was selected as it allows for mixed effects modeling with clustered data, as well as for the use of sampling weights (unlike SAS/STAT software's procedure MIXED). All models assumed a normal response distribution and utilized maximum likelihood estimation with Gauss-Hermite Quadrature approximation, and classical empirical or 'sandwich' estimators (Rabe-hesketh & Pickles, 2002; SAS Institute Inc, 2008). Maximum likelihood estimation accounted for missing data in the dependent variable, while missing data in the explanatory variables was removed via listwise deletion (Allison, 2012).

2.6 Results

Table 2.1 Descriptive statistics (weighted).

Variable	Mean	SE of Mean	Minimum	Maximum
Reading IRT Score	38.60	0.28	12.39	82.48
Math IRT Score	40.40	0.19	11.06	69.69
Number of Asthma Attacks	0.35	0.03	0	40
Time Without Insurance	2.18	0.12	0	64

Table 2.1 presents weighted descriptive statistics for the continuous variables included in this analysis. The model building approach used began with a null model to determine the intraclass correlation coefficient (ICC) or the effect of clustering in the data. Zip codes were used as the level-2 units or cluster variable and as a proxy for neighborhoods, and individual children served

[8] The data analysis for this paper was generated using SAS/STAT® software, Version 9.2 of the SAS System for Windows. Copyright © 2008 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

as the level-1 units. The full dataset includes 10,700 children in 3750[9] zip codes (the weighted sample included only 3700 zip codes). Cluster sizes ranged from one to 20 children per cluster. Tables 2.2 & 2.3 show results of the null models for both reading and math scores, yielding ICCs of 0.769 and 0.770 respectively, suggesting that 77% of the variation in both reading and math scores can be accounted for by neighborhoods.

Table 2.2 Null Models for Reading IRT Scores

Fixed Effect	Coefficient	Standard Error	DF	t-value
Intercept	39.73	0.24	3600	166.18***
Random Effects				
Intercept	206.59	4.50		45.91***
Residual	61.93	2.84		

*p < .05, ** p <.01, *** p <.001

*Observations (n) = 6750, Clusters (N) = 3750

Table 2.3 Null Models for Math IRT Scores

Fixed Effect	Coefficient	Standard Error	DF	t-value
Intercept	40.96	0.17	3650	240.81***
Random Effects				
Intercept	104.64	2.41		43.42***
Residual	31.17	1.51		

*p < .05, ** p <.01, *** p <.001

* n = 6750, N = 3750

Following examination of the null model three separate sets of multi-level models were created to address each research question (RQ – 1a, 1b, & 2). For each set of models, model 1 includes primary level-1 predictors of interest (e.g. for RQ1a. disease status), a second model adds additional level-1 covariates (e.g. race, poverty status, and any other level-1 explanatory

[9] With the exception of the full sample of 10,688 children, all sample and cluster sizes are rounded to the nearest 50 per NCES restricted license procedures.

variables), and a third model includes level-2 predictors (e.g. neighborhood characteristics) and any relevant interactions. All models include urban location as a random effect. The basic system of equations examined for all three sets of models is shown in Figure 2.1.

System of Equations

$$\text{Level 1: Reading score}_{ij} = \beta_{0j} + \beta_{1j}\, X(\text{asthma})_{ij} + \ldots\ \beta_{qj} X_{qij} + \ldots + r_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}\, L(\text{urban location})_{j} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} L_{j} + u_{1j}$$

$$\beta_{qj} = \gamma_{q0} + \gamma_{q1} L_{j} + u_{qj}$$

Y = predicted score for outcome variables ('reading IRT' or 'math IRT' scores)

J = groups (zip codes)

q = due to the large number of predictors used, this represents predictor variables not directly listed in the equation but included in the model

Figure 2.2. System of Equations

For RQ1a an initial model examined the degree to which a child ever having a diagnosis of asthma or a diagnosis of ear infections impacted reading and math assessment scores, Tables 2.4 and 2.5 present the results. Both a prior diagnosis of asthma or ear infections demonstrated statistically significant associations with both reading and math IRT scores. A prior diagnosis of asthma was associated with a 2.24-point reduction in reading IRT scores, and 1.49-point reduction in math IRT scores. A prior diagnosis of ear infections was associated with a 2.25-

Table 2.4. Multi-level model estimates for early childhood illnesses, healthcare access, & neighborhood characteristics on early reading IRT scores.

	Model 1			*Model 2*			*Model 3*		
	Coefficient	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**
Fixed Effect									
Intercept	38.08	0.68	**56.23***	48.47	2.40	**20.18***	56.18	4.55	**12.34***
Asthma	-2.24	0.97	**-2.32***	-1.95	1.14	-1.70	-0.40	1.97	-0.20
Ear Infections	2.25	0.81	**2.77***	2.21	1.04	**2.12***	1.55	1.70	0.91
Health Insurance Coverage				-3.14	1.88	-1.67	-11.17	2.53	**-4.41***
No Access to Healthcare				-2.50	1.79	-1.40	-5.20	6.20	-0.84
Urban Location							2.84	1.09	**2.61***
Safe Neighborhood							2.60	2.34	1.11
Witnessed Violence							-4.00	3.40	-1.18
Black				-5.08	1.66	**-3.06***	-8.88	2.57	**-3.45***
Hispanic				-3.96	1.77	**-2.24***	-4.82	2.48	-1.95
Poverty				-5.86	1.36	**-4.32***	-8.85	2.02	**-4.39***
Near Poverty				-3.00	1.85	-1.62	-3.74	2.75	-1.36
Asthma * No Access to Healthcare							14.43	6.98	**2.07***
Ear Infection * No Access to Healthcare							-6.89	7.03	-0.98
Random Effects									
Intercept	157.96	4.65	**33.97***	134.22	5.71	**23.51***	151.83	10.14	**14.97***
Urban Location	97.65	7.06	**13.83***	94.61	9.13	**10.36***	95.05	12.89	**7.37***
Residual	59.43	2.79		56.80	3.87		30.18	3.48	
Model Fit		**df**			**df**			**df**	
-2LL	12682347	6		5715223	12		2654832	17	
AIC	12682359			5715247			2654866		
BIC	12682396			5715316			2654955		

Table 2.5. Multi-level model estimates for early childhood illnesses, healthcare access, & neighborhood characteristics on math IRT scores.

	Model 1			*Model 2*			*Model 3*		
	Coefficient	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**
Fixed Effect									
Intercept	40.00	0.49	**81.98***	45.65	1.81	**25.18***	51.75	3.76	**13.77***
Asthma	-1.49	0.76	**-1.96***	-1.24	0.89	-1.38	-0.40	1.71	-0.23
Ear Infections	1.29	0.58	**2.24***	1.62	0.75	**2.14***	0.41	1.23	0.33
Health Insurance Coverage				-0.95	1.52	-0.62	-6.95	2.00	**-3.48***
No Access to Healthcare				-1.68	1.34	-1.26	-4.05	4.98	-0.81
Urban Location							2.10	0.74	**2.83***
Safe Neighborhood							0.04	1.67	0.03
Witnessed Violence							-5.79	2.93	**-1.98***
Black				-4.51	1.19	**-3.79***	-5.73	2.16	**-2.65***
Hispanic				-3.39	1.18	**-2.88***	-2.96	2.22	-1.33
Poverty				-2.97	0.98	**-3.02***	-4.07	1.43	**-2.85***
Near Poverty				-2.53	1.22	**-2.07***	-2.41	1.94	-1.24
Asthma * No Access to Healthcare							8.17	4.36	1.87
Ear Infection * No Access to Healthcare							-2.73	5.60	-0.49
Random Effects									
Intercept	80.12	2.65	**30.23***	69.24	3.61	**19.18***	69.57	5.14	**13.54***
Urban Location	46.26	4.66	**9.93***	38.69	5.87	**6.59***	43.85	8.32	**5.27***
Residual	29.93	1.50		29.90	2.19		17.30	1.94	
Model Fit		**df**			**df**			**df**	
-2LL	11444203	6		5197764	12		2431105	17	
AIC	11444215			5197788			2431139		
BIC	11444252			5197857			2431228		

point increase in reading IRT scores, and a 1.29-point increase in math IRT scores. The positive nature of this relationship is an unexpected finding, and may be a result of the fact that ear infections are the most frequently diagnosed illness among young children affecting 75-95% of the population at some point in their life (Racanello & McCabe, 2010). A second model added individual level covariates for race/ethnicity and poverty status to the model. In this model, both Black and Hispanic race/ethnicity covariates and poverty demonstrated statistically significant associations with both reading and math IRT scores. Poverty status as family income below the ‘poverty’ threshold and below the ‘near-poverty’ threshold was significantly associated with math IRT scores, but only ‘poverty’ was significantly associated with reading IRT scores. When controlling for these demographic characteristics asthma is no longer significantly associated with either reading or math scores. A prior diagnosis of ear infections, however, remains significantly associated with both reading and math IRT scores when controlling for race and poverty. A third model added predictors for healthcare access (‘health insurance coverage,’ and ‘no access to health care’) and neighborhood characteristics (‘urban location,’ ‘safe neighborhood,’ and ‘witnessed violence’). Controlling for all other variables having health insurance coverage in the year prior to the assessment was significantly associated with both reading and math scores, as was urban location. Having witnessed violence in the year leading up to the assessment was significantly associated with a reduction of 5.79 points in math IRT scores. Race and poverty covariates remain significant only for children who are Black and below the poverty threshold for both reading and math scores. So, controlling for all other variables, near poverty and Hispanic ethnicity are no longer significantly associated with reading and math scores. The significance of the two illness predictors (asthma and ear infections) changed when healthcare access variables were added to the model. Subsequently, two interactions were added examining both diagnoses and no access to healthcare. The interaction for a history of asthma and no access to healthcare was significant only for reading IRT scores, indicating that lack of healthcare access may serve as a moderator for the impact of asthma on reading assessment scores.

Model fit was assessed using two methods, the Akaike Information Criterion (AIC) and the Deviance. Reductions in AIC across models demonstrates improved model fit. Deviance is the log of the likelihood times negative two (-2LL), comparison of the deviance across models is a second indicator of model fit, where in the case of a hierarchical or nested structure lower deviance indicates an improved model. The difference in deviance fits a chi-squared distribution with number of parameters in the model as the degrees of freedom. While deviance is likely to decrease with the introduction of additional parameters to the model, AIC balances this with the desire for a more parsimonious model by accounting for the increase in parameters. For this reason, model fit was assessed using both methods. Substantial reductions in AIC and deviance indicate model 3 is the better model for both outcome variables (reading and math IRT scores). Further if we examine the change in variance from the null model, we find that the inclusion predictors in model 3 reduces the between cluster variance by 51.27%[10] for reading IRT scores and 44.50% for math IRT scores. Individual within group variance decreases substantially as well indicating that the inclusion of predictors in the full model explain a large percentage of the variance within groups (change in within group variance $= 1 - \frac{model\ 3\ residual}{model\ 2\ residual}$; (1-(30.18/56/80) = 0.4687 or 47%).

[10] pseudo $R^2 = \frac{(\sigma^2 M_0 - \sigma^2 M_3)}{\sigma^2 M_0}$

Table 2.6. Multi-level model estimates for asthma severity & neighborhood characteristics on early reading IRT scores.

	Model 1			***Model 2***			***Model 3***		
	Coefficient	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**
Fixed Effect									
Intercept	39.65	0.32	**125.54***	46.94	1.29	**36.51***	44.45	3.68	**12.09***
Asthma	-2.04	0.97	**-2.09***	-1.61	1.13	-1.42	0.17	2.70	-0.06
Black				-4.91	1.65	**-2.98***	-8.72	2.56	**-3.41***
Hispanic				-3.53	1.77	**-1.99***	-3.02	2.63	-1.15
Poverty				-6.00	1.35	**-4.43***	-8.66	2.25	**-3.84***
Near Poverty				-3.34	1.86	-1.80	-4.18	3.07	1.36
Steroid							4.59	4.44	-1.03
Asthma Rx							0.40	3.61	0.11
Hospitalization							0.08	2.99	0.03
# Asthma Attacks							-0.69	0.32	**-2.13***
Urban Location							2.58	1.05	**2.46***
Safe Neighborhood							3.66	2.20	1.66
Random Effects									
Intercept	156.85	4.57	**34.32***	136.74	5.80	**23.58***	149.34	5.14	**29.05***
Urban Location	97.55	7.09	**13.76***	86.95	8.69	**10.01***	91.12	8.32	**10.95***
Residual	59.73	2.81		58.04	3.97		32.53	1.94	
Model Fit		**df**			**df**			**df**	
-2LL	12700480	5		5759042	9		2756477	15	
AIC	12700490			5759060			2756507		
BIC	12700520			5759111			2756586		

Table 2.7. Multi-level model estimates for asthma severity & neighborhood characteristics on math IRT scores.

	Model 1			***Model 2***			***Model 3***		
	Coefficient	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**
Fixed Effect									
Intercept	40.93	0.23	**176.75***	45.91	0.87	**52.71***	43.51	2.81	**15.49***
Asthma	-1.37	0.77	-1.80	-0.97	0.88	-1.10	-0.91	1.97	-0.46
Black				-4.44	1.18	**-3.78***	-6.21	2.16	**-2.87***
Hispanic				-3.28	1.18	**-2.78***	-1.37	2.26	-0.61
Poverty				-3.04	0.96	**-3.16***	-4.53	1.55	**-2.92***
Near Poverty				-2.84	1.22	**-2.31***	-2.50	1.99	1.26
Steroid							2.44	3.34	-0.73
Asthma Rx							-0.16	3.02	0.05
Hospitalization							2.82	2.38	1.19
# Asthma Attacks							-0.51	0.28	-1.86
Urban Location							2.11	0.72	**2.93***
Safe Neighborhood							1.13	1.67	0.68
Random Effects									
Intercept	80.22	2.65	**30.27***	71.57	3.79	**18.89***	72.70	5.87	**12.39***
Urban Location	45.69	4.62	**9.89***	33.13	5.76	**5.75***	44.17	9.35	**4.72***
Residual	30.02	1.51		30.40	2.24		18.75	2.15	
Model Fit		**df**			**df**			**df**	
-2LL	11457892	5		5759042	9		2529266	15	
AIC	11457902			5759060			2529296		
BIC	11457933			5759111			2529375		

Given that initial models indicated a significant association between asthma and reading and math IRT scores that disappears when controlling for other variables, a second set of models was developed to examine the impact of asthma severity (RQ1b), Tables 2.6 and 2.7 present the results. A base model was created similar to that of RQ1a, but no longer controlling for a history of ear infections. A prior diagnosis of asthma demonstrated statistically significant associations with reading but not math IRT scores when no other predictors are included in the model ($ß_{1j}$ = 2.04 for reading scores). Similar to RQ1a when controlling for race and poverty status asthma no longer demonstrates a significant association with reading IRT scores. In this second model, both Black and Hispanic race covariates and poverty demonstrated statistically significant associations with reading IRT scores, whereas Black, Hispanic, poverty, and near-poverty demonstrated statistically significant associations with math IRT scores. A third model added predictors for asthma severity ('steroid,' 'asthma Rx,' 'hospitalization,' and '# of asthma attacks') as well as neighborhood characteristics ('urban location,' and 'safe neighborhood'). In this final model urban location was the only neighborhood characteristic significantly associated with both reading and math IRT scores. Of the asthma severity indicators, only one demonstrated a significant association with assessment scores. Number of asthma attacks was significantly associated with reading IRT scores ($ß_{9j}$ = -0.69). Race/ethnicity and poverty covariates remain significant only for children who are Black and below the poverty threshold for both reading and math IRT scores in the final model. Model fit was again assessed using both AIC and the deviance. Substantial reductions in both AIC and deviance indicate model 3 is again the better model for both outcome variables (reading and math IRT scores). Pseudo R^2 values for this set of models is similarly high (47.47% for reading IRT scores, and 39.85% for math IRT scores) indicating the predictors included substantially improve the model.

Table 2.8. Multi-level model estimates for healthcare access and place for routine care on early reading IRT scores.

	Model 1			*Model 2*		
	Coefficient	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**
Fixed Effect						
Intercept	41.36	1.97	**21.05***	41.90	2.67	**15.69***
Asthma	-2.07	0.97	**-2.14***	-2.43	0.96	**-2.53***
Health Insurance Coverage	-1.60	1.96	-0.82	-1.31	1.91	-0.69
No Access to Healthcare	-2.09	1.54	-1.36	-1.37	1.53	-0.90
Time without Insurance	-0.02	0.07	-0.35	0.02	0.07	0.23
Clinic or Healthcare Center				-4.29	2.13	**-2.01***
Emergency Room				-7.99	2.42	**-3.30***
Doctor's Office or HMO				0.83	1.88	0.44
Hospital Outpatient Dept.				-1.00	3.27	-0.31
Not One Place				-1.15	1.17	-0.99
Random Effects						
Intercept	155.66	4.61	**33.77***	152.61	4.59	**33.25***
Urban Location	94.98	7.07	**13.43***	89.01	6.76	**13.17***
Residual	59.24	2.78		57.37	2.67	
Model Fit		**df**			**df**	
-2LL	12608392	8		12539269	13	
AIC	12608408			12539295		
BIC	12608458			12539376		

Table 2.9. Multi-level model estimates for healthcare access and place for routine care on math IRT scores.

	Model 1			***Model 2***		
	Coefficient	**SE**	**t-value**	**Coefficient**	**SE**	**t-value**
Fixed Effect						
Intercept	42.07	1.59	**26.43***	41.67	1.98	**21.09***
Asthma	-1.40	0.76	-1.84	-1.65	0.75	**-2.20***
Health Insurance Coverage	-0.89	1.59	-0.56	-0.64	1.52	-0.42
No Access to Healthcare	-2.36	1.16	**-2.03***	-1.85	1.14	-1.62
Time without Insurance	-0.06	0.06	-0.96	-0.03	0.06	-0.50
Clinic or Healthcare Center				-2.47	1.41	-1.76
Emergency Room				-5.67	1.73	**-3.28***
Doctor’s Office or HMO				1.36	1.39	0.98
Hospital Outpatient Dept.				-0.37	2.49	-0.15
Not One Place				-0.53	0.87	-0.61
Random Effects						
Intercept	79.35	2.69	**29.50***	76.49	2.61	**29.31***
Urban Location	44.17	4.72	**9.36***	43.26	4.25	**10.18***
Residual	29.69	1.50		28.64	1.44	
Model Fit		**df**			**df**	
-2LL	11368201	8		11293245	13	
AIC	11368217			11293271		
BIC	11368267			11293351		

The initial set of models yielded a third interesting finding regarding healthcare access. While the initial associations found for both asthma and ear infections with reading and math scores disappear in the full model, a new association between health insurance coverage becomes significant. Further lack of healthcare access appears to moderate the relationship between asthma and reading scores. To further examine these relationships a third set of models was developed to address health care access (RQ2). These models examine both original access variables (health insurance coverage and no access to healthcare) and add a continuous variable for the amount of time the child went without health insurance and a set of variables representing place for routine medical care, Tables 2.8 and 2.9 present the results. Building from the base model demonstrating the relationship between asthma and reading and math IRT scores (Tables 2.6 & 2.7, model I), an initial model was created adding all three explanatory variables describing healthcare access (‘health insurance coverage’ and ‘no access to care,’ and ‘time without insurance’). In this model, for reading asthma remains significantly associated with assessment scores, but no healthcare access variables demonstrated a significant association. For math while asthma does not remain significantly associated with assessment scores, a lack of access to healthcare does demonstrate a significant association with a 2.36-point reduction in the math IRT scores for children without access to care. A second model included the location for routine medical care (‘clinic or health care center,’ ‘emergency room,’ ‘doctor’s office or HMO,’ ‘hospital outpatient department,’ or ‘not one place’). For these five variables, both ‘emergency room’ and ‘not one place’ examine whether parents ever indicated these as their primary place for care, whereas the remaining variables only reference the third round of data collection. Both clinic or healthcare center and emergency room were significantly associated with reductions of 4.29 and 7.99 points respectively in reading IRT scores. For math, only emergency room use was significantly associated with scores, with a reduction of 5.67 points in the math IRT score. Similar to the first two sets of models, both AIC and deviance demonstrate a smaller but still substantial decrease across these models, indicating that model 2 is the better model. An examination of pseudo R^2 values for these full models (with values of 7.36% for reading IRT scores, and 8.12% for math IRT scores) indicate that like the first two sets of models the inclusion of these healthcare access predictors improve the model but not to the same degree.

2.7 Discussion

These results reveal interesting relationships between early childhood health and school readiness outcomes. Specifically, while asthma and ear infections (the most common chronic and recurrent illnesses experienced by children) initially appear to be significantly associated with assessment scores, when we control for race/ethnicity, poverty, and healthcare access, the relationship disappears. This suggests that perhaps there are other factors that may both impact readiness individually, and moderate this relationship. In the initial set of models, health insurance coverage was significantly associated with both reading and math scores, and interestingly access to health care appears to serve as a moderator for the impact of asthma on reading assessment scores. Controlling for health experiences, Black children in poverty have lower reading and math scores. While living in urban areas had a positive impact on both reading and math scores, witnessing violence had a stronger negative impact on math scores.

When examining asthma severity, similar results were found. When controlling for race and poverty status and neighborhood characteristics, the relationship between asthma and assessment scores for both reading and math disappears. Living in an urban area continues to positively impact scores even when controlling for severity of asthma. Interestingly, only number of asthma attacks had a significant impact and only in the area of reading. When examining parameter estimates, it is also interesting to note that asthma severity had a substantially smaller impact on average scores than did healthcare access or neighborhood characteristics. This further suggests that it is not necessarily the presence of the chronic disease itself operating directly to negatively impact student's scores, but perhaps the child's access to care or lack thereof that has the stronger influence.

Taken together, these initial results address the first research question, "Do early childhood health experiences (i.e. chronic or recurrent illness, access to health care, etc.) impact children's reading and math skills at or before kindergarten entry? How do demographic (i.e. race and income) and neighborhood characteristics (i.e. safety, urban location) affect these relationships?" These findings suggest that yes, early childhood health experiences do in fact impact children's reading and math skills at kindergarten entry. More specifically, these findings suggest that healthcare access, and potentially severity of disease have significant impacts on early reading and math skills. They further suggest that when controlling for neighborhood characteristics, as well as healthcare access and asthma severity, the relationship remains only for Black children and those with household incomes below the poverty threshold. The positive relationship found for living in an urban area is likely related to the broad definition of 'urban' encompassing both central cities and surrounding metropolitan areas. An analysis examining differences based upon neighborhood type with more narrowly defined parameters may yield more insight into this finding. Additionally, the significant relationship between witnessing violence and math scores would benefit from further analysis.

The final set of analyses address the second research question, "What is the relationship between children's access to health care (i.e. health insurance coverage, access to care, place for regular care, etc.) and their kindergarten/school readiness?" Overall results suggest that use of the emergency room for primary or routine care is associated with significantly lower reading and math assessment scores. Interestingly, use of a clinic or health care center for routine care also demonstrated a significant negative impact on assessment scores for reading. These results suggest that place of care and potentially access to physicians and annual physicals is also associated with early academic achievement.

When considering the examination of neighborhoods used in this study, it is important to note that many large national datasets sample schools, not neighborhoods. Those that do utilize a 'neighborhood' level sampling frame often end up with sparse data. Specifically, these population-based datasets often start with a large number of groups with smaller group sizes. Over time, the potential for attrition may further reduce cluster size (Clarke, 2008; Theall et al., 2011). Nationally representative survey datasets such as this one have traditionally been used to examine student and school level variables and relationships. While examination of neighborhood effects on educational outcomes is by no means new, these national education surveys are more frequently being used to do so. As more analyses begin to look at neighborhood or family level cluster, the issue of small cluster sizes has become a more relevant concern. Clarke, (2008) examined cluster sizes and suggested that both valid and reliable parameter estimates and variance components can be obtained, with as few as five units per group or cluster. The author further found no bias for cluster sizes as small as two units, when using balanced data and a large number of groups (N = 200). Theall et al (2011) expanded on the work of Clark (2008) and their results found no bias in fixed or random parameter estimates with a large number of clusters and small cluster size. Specifically, they note that "even with a group size of one in 90% of census tracts, there is little impact on average estimates and only slight differences in the magnitude of the random components and the ICC" (p. 691). While sparse data exists in this analysis, these findings suggest that based upon the large sample size and more importantly the large number of clusters, parameter and variance estimates remain valid and reliable.

2.8 Conclusion

Prior research suggests that the relationship between race and asthma disappears when controlling for zip code (Basch, 2011a, 2011b). While these results do not control for neighborhood, they do indicate that clustering at the neighborhood level does have an impact on the relationship between these early childhood health experiences and reading and math assessment scores. In addition to findings related to healthcare access, a more nuanced examination of neighborhood characteristics may yield more detail regarding the relationship between early childhood health and education. Further, continued examination of the relationships between recurrent illnesses like ear infections including factors like severity and treatment may further elucidate another path through which early health experiences may impact children's development.

Consistent with prior research, race and income continue to demonstrate a substantial impact on educational outcomes. Further examination of the nature of the relationship between race, income, early childhood health experiences, and outcomes may prove informative. Examining not only the impact of factors like race and poverty, but further examination of how these factors operate both differentially across space or neighborhoods, and in interaction with health outcomes as well may better define the relationships. While important, poverty is an extreme condition and may miss differences based upon income or socioeconomic status at higher income levels (those above poverty or near poverty). The inclusion of more variables related to family income may further clarify the relationship between early childhood health experiences and academic outcomes. For example, examining a continuous measure of socioeconomic status, or a categorical variable that includes outcomes across the continuum from poverty to affluence.

Literature suggests that there is a causal relationship whereby increasing one's education increases one's health, and the reverse (Eide & Showalter, 2011; Haas, Glymour, & Berkman, 2011). This study builds upon these understandings about the interdependence of health and education and seeks to contribute new evidence by demonstrating that adverse early childhood health experiences (i.e. chronic illness), family characteristics (i.e. minority and poverty status), neighborhood characteristics (i.e. neighborhood poverty, crime, and urban locality), and limited healthcare access are 'out-of-school' factors that taken together negatively impact reading and math assessment skills at kindergarten entry. These findings more specifically demonstrate that not only investment in early childhood education, but also investment specifically in early childhood health outcomes, such as healthcare access, are critical to education policy.

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2.10 Appendices

Appendix 2A. Variable List (actual variable names suppressed due to restricted nature of dataset).

Variable	Variable Description	Source
Child Characteristics		
Child Race	Children's Race/Ethnicity	Variable obtained from the child's birth certificate
Poverty	Poverty	Indicator composite variable based upon family's income level – for income below the poverty threshold
Near Poverty	Near Poverty	Indicator composite variable based upon family's income level –for income below 185% of the poverty threshold
Chronic or Recurrent Illnesses		
Asthma	Used to create composite across rounds 1-4	Parent survey question asking parents "Has a doctor, nurse, or other medical professional ever told you that [child/twin] has…asthma?"
Ear Infection	Used to create composite across rounds 1-4	Parent survey question asking, "Has a doctor, nurse, or other medical professional ever told you that [child/twin] has…an ear infection."
Severity of asthma will be examined using the following three variables.		
Asthma Rx	Medication for asthma	Survey question asking parents "why does [child/twin] have to take this medicine? Is it for…asthma?"
Steroid	Steroid treatment for asthma	Survey question asking parents "How was [child's/twin's] most recent episode of asthma treated by your doctor, nurse or other medical professional? Steroid/Anti-Inflammatories"
Hospitalization	Hospitalization for asthma	Survey question asking parents "Has [child/twin] ever been taken to an emergency room or hospitalized for at least one night because of asthma?"
Asthma Attacks	Number of asthma attacks	Survey question asking, "How many times has a doctor, nurse, or other medical professional told you that [child/twin] had an asthma attack?"
Healthcare/Health Insurance		
Health Insurance Covered	Child covered by insurance	Parent survey question asking "Is the [child/twin] covered by any kind of health insurance or some other kind of health care plan?"
Time without Insurance	Number of months without insurance coverage	Parent survey question asking "About how many months was [child/twin] without health insurance or health care coverage?"
Access to Healthcare	No access to healthcare	Parent survey question asking 'Has there been a time when [child/twin] needed but could not obtain healthcare?'
Place for Medical Care	Place for regular medical care	parent survey item asking, "Where do you usually go for routine medical care?"
Neighborhood Characteristics		
Safe Neighborhood	Safe Neighborhood	Parent survey question asking parental perception of level of neighborhood crime
Violent Neighborhood	Witnessed Violent	Parent survey question asking if parents or children have witness a violent act in their neighborhood or home
Urban Location	Urban Area	Parent survey question asking type of neighborhood (urban, suburban, rural)
School Readiness Variables		
Reading IRT Score	Early Reading IRT Score	KDG 2006 Early Reading Assessment IRT Scale Score
Math IRT Score	Math IRT Score	KDG 2006 Mathematics IRT Scale Score
Weight Variable		
Weight	Fourth round full sample weight	This weight is adjusted for non-response to the parent interview. Per ECLS-B manual this weight is used for both the parent-interview and child assessment for this round only.

Chapter 3

Race, Space, and Education Research: Revisiting Tobler's First Law of Geography

> Racial research has a long and controversial history. At the turn of the 20th century, sociologist and civil rights leader W. E. B. Du Bois was the first to synthesize natural and social scientific research to conclude that the concept of race was not a scientific category. Contrary to the then-dominant view, Du Bois maintained that health disparities between blacks and whites stemmed from social, not biological, inequality… Today, scientists continue to draw wildly different conclusions on the utility of the race concept (Yudell, Roberts, DeSalle, Tishkoff, 2016, p. 564)

> "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970)

3.1 Introduction

The argument expressed in the first quotation from a group of biologists reflects the state of affairs on the use of race as a construct in human genetics. As a result of advances in molecular genetics, scientists have examined populations of species and subspecies and reconstructed their evolutionary histories on the basis of objective methods, rather than ideologically based social constructions. The current state of evidence in science indicates that biological races (or subspecies) do not exist among modern humans and have never existed (Sussman, Allen, & Templeton, in press). Templeton (1998) characterized the extensive evidence of genetic interchange through population movements and recurrent gene flow going back over the course of history, and captured the current position in genetics: “Human evolution and population structure has been characterized by many locally differentiated populations coexisting at any given time, but with sufficient contact to make all humanity a single lineage” (p. 647). Thus, a difficult question faces social scientists: Are race-based predictions in clinical and educational settings useful in light of the heterogeneous nature of racial groups, especially as the frequency of admixture rises across populations?

Yudell, Roberts, DeSalle, & Tishkoff (2016) argued that scholars need to attend more carefully to their use of racial categories, whether they focus on racism (i.e., social relations) or race (i.e., “supposed’ innate biologic predisposition) in their interpretations of racial/ethnic effects. In this chapter, we describe the relative value of understanding race, education, and the social environment. Here, we do not construct race on the basis of biological predispositions. Instead, the investigation seeks to understand locally differentiated geospatial relations that represent a product of long-standing social relationships influenced by preferences and discrimination. Tobler’s (1970) First Law of Geography, as stated in the second quotation above, will influence the review and analysis in this chapter. The law applies to the study of schools and education. Neighboring school districts reflect clustering created by spatial proximity that produces unique local contexts and concomitant within-group correlation (Hogrebe & Tate, 2015). In many cases, families and students within school districts tend to share common characteristics on demographic and social factors, such as education, income, and housing. Also often the fairly homogenous built environment within districts plays a substantial function and gives distinctiveness to the local context. But this similarity in demographic and social characteristics as well as in the built environment does not begin and end suddenly at district boundary lines. Instead, a case exists for reasoning that similarity based on spatial proximity framed as a continuum, which does not start and stop at socially constructed borders, such as district boundaries represents a more accurate description. Similarity to dissimilarity across local contexts functions as a continuum in geographic space. Understanding this continuum provides insight into race as a product of long-standing social relationships.

3.1.1 Local Conditions versus Biology

Du Bois posited that racial health disparities were the result of social relations and local conditions, not biological differences. It would be convenient to argue that this chapter represents a continuation of Du Bois's conceptual approach with more advanced methods and computational capacity. The temptation is great but for Ralph Ellison's cautionary warning concerning social science and the study of race. In his review of Gunnar Myrdal's now classic study, *An American Dilemma: The Negro Problem and Modern Democracy*, Ellison (1944) wrote the following statement about the role of social science over the course of United States history:

> This was a period, the 1870s, wherein scientific method, with its supposed objectivity and neutrality to values, was thought to be the answer to all problems. There is no better example of the confusion and opportunism springing from this false assumption than the relation of American social science to the Negro problem. And let us make no easy distinctions here between Northern and Southern social scientists; both groups used their graphs, charts and other paraphernalia to prove the Negro's biological, psychological, intellectual and moral inferiority, one group to justify the South's exploitation of Negroes, and the other to justify the North's refusal to do anything basic about it. (Ellison, 1944, n.p.)

Ellison critiqued social scientists' efforts to appear unconcerned about values, while simultaneously working to reconcile the morality of American capitalism with the moral project associated with the American Creed. Ellison's argument does not fall outside the norm found in more recent descriptions of American social science. For example, Kenneth Prewitt (2005) posited that, like science more generally, American social science has, since its inception, revolved around two inseparable projects: a science project (more in-depth understanding of institutions, organizations, human decision-making, and so on); and a national political project (protecting the nation, building the economy, strengthening democracy, etc.). He reasoned further that American social sciences are American-centric. He describes social science as a part of the contingent social systems that attach meaning to and reinforce the meanings interpreted as race. This meaning includes morphology, social processes, and distributions of wealth and poverty with characteristic resulting material conditions (Carter & Goodwin, 1994; Haney Lopez, 1996). The Ellisonian perspective on social science warrants attention. Specifically, social scientists must address presuppositions prior to an analysis of race, space, and education. The presuppositions in this chapter include the following.

1. In U. S. society, racism is endemic and deeply ingrained legally, culturally, and psychologically (Bell, 2008; Katznelson, 2005).

2. Statistical methods should not displace historical examinations of social conditions involving schools, education, and race. Rather, statistical methods and history should complement each other. In research on race, ahistorical research approaches are dangerous and risk losing important pre-conditions (Margo, 1990; Spencer, Tinsley, Dupree, & Fegley, 2012).

3. Racial categories based on biological classifications are rejected. Nevertheless, it is nearly impossible to conduct research on social relationships without using classification schemes deeply influenced by racist depictions based on pseudoscience. It is acknowledged as a limitation and, where possible, language use and interpretation focus on forces, conditions, events, and processes (Ladson-Billings & Tate, 1995).

The presuppositions inform the approach used in the chapter. This chapter does not include a comprehensive review of the uses of geography and education (see e.g., Hogrebe and

Tate, 2012). Nor does it represent an expansive review of race and education (Tate, 1997). Instead, the chapter contributes a case study of Missouri as an example of analyzing the role of geography, race, and education. The first section reviews how race and space have been conceptualized and studied to assess influences on developmental outcomes including education. The second section offers a historical perspective on the case. Missouri provides a paradigmatic view into social relations and the dynamics of race. The third section describes an analytical approach used to study the relationship between race, space, and education as part of a state-level analysis. We discuss results in light of Tobler's First Law of Geography. We aim to demonstrate how race operates differently across space. The final section reflects on lessons learned and directions for future research.

3.1.2 Race, Space, and Developmental Outcomes

Within the past two decades, scholars have refocused their attention on the effects of geospatial factors and social context on child and adolescent developmental outcomes, including those related to education and health (e.g., Hogrebe & Tate, 2012; Spencer, Tinsley, Dupree, & Fegley, 2012; Tate & Hogrebe, 2011; Yeakey, 2012). This renewed focus on the influence of geospatial and social-contextual characteristics on development is acutely significant for poor, urban youth living in segregated communities. Compared to their peers in more affluent communities, these youths generally are confronted with differential regulatory experiences and a more limited set of developmental opportunities. Galster (2012) described such constraints as an urban opportunity structure with geographically varying sets of institutions, systems, and markets that shape individual and intergenerational outcomes associated with growth, development, and well-being. The opportunity structure includes local political affairs, criminal justice and social service systems, employment and housing markets, financial services, and schooling. Across socially constructed boundaries, such as school districts, the opportunity structure functions differently and, depending on geospatial location, either facilitates or impedes individuals' positive life chances.

In this section, we review briefly literature examining the influence of school district factors on student academic achievement. We focus specifically on district composition, student behavior, and high school completion factors. We note that most of the reviewed studies focus on the association between school-level factors and achievement. However, as previously described, schools within the same district often share similar characteristics. Thus, aggregating school-level data to examine district-level relationships is warranted and increasingly common in the research literature (Slavin, Cheung, Holmes, Madden & Chamberlain, 2013).

District Composition Factors and Student Achievement

In the United States, race and socioeconomic status (SES) correlate highly and influence several key developmental outcomes, including those in education and health (Cheng et al., 2015; Hogrebe & Tate, 2010). Several researchers have demonstrated that both the racial and socioeconomic composition of schools independently affect student achievement (Logan, Minca, & Adar, 2012; Logan & Oakley, 2012; Perry & McConney, 2010; Rumberger & Palardy, 2005; Sirin, 2005). Some evidence indicates that the relationship between district socioeconomic composition and student achievement, for example, varies by geographic location (Hogrebe & Tate, 2013). Schools and districts with high percentages of non-White and of low-income students, respectively, tend to have lower academic achievement. Hogrebe and Tate (2010) found that the proportions of non-White and of low-income students were negatively associated with tenth-grade science proficiency across Missouri high schools. Even more, non-White and low-income percentage respectively moderated relationships between other school-level contextual characteristics and science proficiency.

Student Behavior Factors and Student Achievement

Regardless of a student's race or SES, attending school daily is necessary for learning and achieving academically (Balfanz & Byrnes, 2012). Although scant, research literature investigating the connection between student attendance and school achievement supports this notion (Konstantopoulos, 2006; Lamdin, 1996). Roby (2004) examined, at the school level, the relationship between annual building average attendance and student achievement on the Ohio Proficiency Tests. Across several grades, student attendance and achievement correlated positively, with the correlation strongest for ninth-grade students. In light of his findings, Roby suggested that additional studies, including those assessing the influence of school size on the attendance–achievement connection, be conducted.

Extant evidence indicates that school discipline incident rate is also associated with student academic achievement (Gregory, Skiba, & Noguera, 2010; Raffaele Mendez, 2003). Raffaele Mendez (2003) found that increased issuance of school suspensions and expulsions, for example, increased the risk of lower achievement. After accounting for the effects of demographic factors, Skiba and Rausch (2004) found that out-of-school suspension rates correlated negatively with school passing percentage on the Indiana State Test of Educational Progress (ISTEP). Compared to students of other races, Black students were more likely to experience negative consequences associated with high suspension rates. This relationship was significant at both the elementary and high school levels, yet stronger for high schools. Moreover, the authors noted that school location influenced discipline rates.

High School Completion Factors and Student Achievement

Closely associated with rates of out-of-school suspensions, high school dropout rate represents another factor that negatively affects school-level achievement (Hogrebe & Tate, 2010; Rumberger & Palardy, 2005). High school dropout rate may indirectly indicate the quality of the school environment and, more specifically, administrators' collective capacity to address challenges. When high, rates of dropping out may point to low collective capacity to respond successfully to problems among students. Comparatively high rates of dropping out may impede achievement at the school level. Thus, school and school district administrators have an important incentive to increase graduation rates. In 2014, the U.S. graduation rate was 82%, the highest level since states adopted a uniform method of calculating graduation rates in 2010 (U.S. Department of Education, 2015). Schools and districts' implementation strategies to increase graduation rates warrant examining the impact of graduation rates on student achievement.

3.1.3 History and Demography of a Border South State

Missouri played a central role in the history of race in the United States. Admitted to the Union in 1821 as part of a two-part strategy known as the Missouri Compromise, it joined as a slave state with Maine entering as a free state to preserve the political balance on the institution of slavery. Representative Charles Kinsey of New Jersey captured the essence of the compromise:

> We have arrived at an awful period in the history of our empire, when it behooves every member of this House now to pause and consider that on the next step we take depends the fate of unborn millions. I firmly believe that on the question now before us rests the highest interests of the whole human family. Now, sir is to be tested, whether this grand

> and hitherto successful experiment of free government is to continue, or after more than forty years enjoyment of the choicest blessings of Heaven under its administration, we are to break asunder on a dispute concerning the division of territory…Do our Southern brethren demand an equal division of this wide-spread fertile region…No; they have agreed to fix an irrevocable boundary, beyond which slavery shall never pass; thereby surrendering to claims of humanity and to the non-slaveholding states (Admission of Missouri, 1820, pp.1578–79)

Representative Kinsey initially voted against allowing slavery in Missouri; however, his position evolved, and, on the Congressional floor, he argued in support of Southern congressmen’s desire that Missouri become a slave state. A majority of Congress concurred. In addition, Congress voted to prohibit slavery in all new states granted admission to the Union from Louisiana Purchase lands north of the southern boundary of Missouri. Thus, Missouri served as a geographic racial marker, a symbolic threshold representing the boundary line of basic liberty.

According to Morris and Monroe (2009), Missouri’s entry into the Union as a slave state positioned it politically and socially with the historical South. Primarily driven by the desire to maintain or expand slavery, secession from the Union during the Civil War links the states commonly viewed as the South. While not included in the 16 states classified as southern states by the U. S. Census, the view of Missouri as border South captures its alignment with the region’s institutionalized slavery. A major slave auctioning center during the 1850s, St. Louis City, Missouri, housed over two dozen agents serving buyers from the lower Mississippi River (“Preservation Plan for St. Louis,” 1995). The state maintained a Confederate government in exile during the Civil War. Missouri's origin and role as a political boundary situate it as a part of the history of the South.

In terms of demographics, new Missourian's migrated to the state from the southern parts of the country. Kirkendall (1986) described the influence of southern White migrants, from most notably Little Dixie, an area in northeast and central Missouri, and west of Little Dixie along the Missouri River to Jackson County stating, "Many identified with the southern way of life and celebrated Confederate holidays" (p. 10). Furthermore, Tennesseans of both Confederate and anti-Confederate sentiment developed the Ozarks and the Bootheel.

With respect to the black population by 1910, Missouri was the only U. S. state outside of the census classification of southern state to have more than a five percent Black population. The percentage of Blacks in Missouri was larger than that in northern states, yet significantly smaller than that in other former slave states of the South.

Over time, Missouri remained largely composed of Whites and Blacks. United States Census Bureau (Quick Facts Missouri, n.d.) estimates of the 2015 racial composition of Missouri indicated that White (83.3%) and Black or African American (11.5%) races predominate, while Hispanic or Latino (4.1%) and Asian (2%) follow. St. Louis City, defined as both a city and county, represents the only majority African American county outside of the census-based definition of southern counties.

3.2 Research Questions/ Purpose

Given this history of Missouri as a border south state, examinations of the relationship between social, political, and educational contexts must consider the influence of not only race and other social processes on outcomes such as academic achievement, but also geography. Place matters, and, as such, the nature of the relationships between these social forces may vary according to space. In this case study of Missouri, we sought to examine whether race, poverty, and in-school factors operate differentially across space and specifically how this variation impacts student achievement within school districts in the state. Do relationships between race and other variables impact student achievement in a stationary or non-stationary fashion? Specifically, we list our research questions below:

- What is the relationship between demographic variables, such as race and poverty, and student achievement? Do these relationships vary geographically across the state of Missouri?
- What is the relationship between attendance rate and student achievement? Does this relationship vary geographically across the state of Missouri?
- What is the relationship between discipline and student achievement? Does this relationship vary geographically across the state of Missouri?
- What is the relationship between district high school completion variables (drop-out rate and graduation rate) and student achievement? Do these relationships vary geographically across the state of Missouri?

3.3 Methodology

3.3.1 Data Sources

We obtained school composition and achievement data from the Missouri Department of Elementary and Secondary Education (DESE) and shape files for Missouri school districts from the United States Census Bureau Tiger Line files for elementary, charter, and unified school districts. For the 2014–2015 school year, the state of Missouri had a total of 557 school districts. Of these 557 districts, 72 districts represented elementary school districts, 448 unified school districts (including both elementary and secondary schools), and 37 charter school districts. The data included in this study include all 557 Missouri districts; however, we collected data specific to graduation rate and dropout rate variables only at the secondary level and were only available for 434 of the 448 unified districts.

Variables and variable descriptions can be found in Table 3.1. Demographic variables examined included percentage of students receiving *Free and Reduced Price Lunch (FRPL)* and percentage of *Non-White* students. In prior years Missouri has measured attendance as an overall average, or an average daily attendance rate. This has recently changed, and now DESE measures attendance as a "proportional attendance rate," or the rate at which schools or districts have at least 90% of students in class 90% of the time. In this study, we use "proportional attendance rate" as the measure of *Attendance.* We measured discipline using the number of students suspended for 10 or more consecutive days (*Suspension >10 days)*, and school completion measures included both *Dropout Rate* and *Graduation Rate*.

The study examined *Achievement* as the dependent variable in all analyses. We created a composite variable for achievement in SPSS using 2015 Missouri Assessment Program (MAP) and End of Course (EOC) results for each district. Study participants obtained MAP and EOC results for English Language Arts (ELA) and Mathematics, including all students enrolled in each district for a full year and took all required assessments from DESE. We reported data as the percentage of students scoring below basic, basic, proficient, or advanced in English Language Arts and Mathematics. Percentages for ELA included subject area MAP scores for grades 3–8 and EOC exam scores for English II. Percentages for Math included subject area

MAP scores for grades 3–8 and EOC exam scores for Algebra I. Researchers created composite *Achievement* scores for each district in SPSS by using a weighted average of the ELA and Mathematics district scores for students scoring in the top two categories (proficient or advanced), where the number of "reportable" students for each category served as the weights. The number of reportable students equated to the number of enrolled students with a valid MAP score. The new *Achievement* variable represents the percentage of students scoring proficient or advanced in ELA and Mathematics for each district.

Table 3.1 Variables

Free and Reduced Price Lunch (FRPL)	Percentage of students receiving either free or reduced price lunch as determined by their family income level.
Percentage Non-White	Percentage of students that are not considered white based on school demographic information
Attendance Rate	Measured as the proportional attendance rate, or a measure of at least 90% student attendance in class 90% of the time.
Discipline (Suspension >10 days)	The number of students who are suspended for 10 or more consecutive days
Graduation Rate	The number of students who graduate in four (4) years with a regular high school diploma divided by the number of students who form the adjusted cohort for the graduated class rounded to the tenth.
Drop-out Rate	For grades 9-12 the number of dropouts divided by the total of September enrollment, plus transfers in, minus transfers out, minus dropouts, added to September enrollment, then divided by two.
Achievement	A composite variable for achievement representing the percentage of students scoring proficient or advanced English Language Arts, & Mathematics for each district was created in SPSS using 2015 Missouri Assessment Program Results. These scores include all students who were in each district for a full year and had valid or 'reportable' scores for the required assessments. Content area scores included percent of students scoring proficient or advanced on the following assessments: English Language Arts (grades 3-8), Math (grades 3-8), and End of Course Exams for Algebra I, and English II.

3.3.2 Analytic Approach

Considering the presuppositions of this chapter and the possibility that race may operate differentially across space, we believe we must examine both local and global relationships between the variables. To do so, we used both ordinary least squares (OLS) regression analysis and geographic weighted regression (GWR) analysis in ArcGIS 10.3 (ESRI, 2015) software.

OLS regression attempts to find the best fit line representing the relationship between two variables of interest and assigns equal weighting for each data point in the analysis. Thus, OLS regression eliminates the significance of location. OLS assigns a global coefficient and R^2 and assumes that the relationship between variables is consistent across the area in question. The simple regression equation demonstrates a spatial stationarity and, hence, suggests that each value of our dependent variable (*Y*) equals the intercept (*a*), or the value of our dependent variable (*Y*) if our predictor variable (*x*) is 0, plus the coefficient (*b*), or slope of the regression line, multiplied by *x*.

$$Y_1 = a + bx_1 \quad (3.1)$$

If the relationship between variables changes across the area examined, then the slope of the regression line should vary or be influenced by geographic region or data point location and proximity to other data points. This variability indicates spatial heterogeneity, or non-stationary relationships, and is lost in OLS. In such circumstances, a method for accounting for the regional variation or non-stationary nature of the relationships is necessary.

GWR allows for regional variation in the relationships between variables by allowing regression model coefficients to vary across a particular geographic space. In contrast to the global values obtained by OLS regression, GWR obtains local values by running separate regression equations for each feature or data point, in our case districts, being examined. Differing from multiple regression or multi-level modeling, where slopes may also vary randomly, GWR coefficients are not random but specific to location by geographic weighting. Each district or polygon is weighted according to its location, such that data points located close to the regression point receive a greater weight than those located further away (Fotheringham & Rogerson, 2009). To assign weights, GWR can use either a fixed or adaptive spatial kerning method. In fixed spatial kerning , the bandwidth of the weighting equation, or change in the effect as the distance away from the data point increases, remains constant regardless of the density of the data points in the region (Fotheringham, Brunsdon, & Charlton, 2002). This leads to potentially increased standard errors of parameter estimates in cases where data points are more sparsely located. Alternatively, adaptive spatial kerning allows for an adaptive or varying weighting function dependent upon the density of data points or optimal number of nearest neighbors (Fotheringham & Rogerson, 2009). In GWR the simple OLS regression equation is modified to account for this weighting, where *i* represents the location for each data point at which *Y* and *x* are measured (Fotheringham & Rogerson, 2009).

$$Y_i = \beta_{0i} + \beta_{1i} x_{1i} + \beta_{2i} x_{2i} + \ldots \beta_{ni} x_{ni} + e_i \qquad (3.2)$$

In this analysis, we examined whether the relationships between the variables of race, poverty, discipline, dropout rate, and graduation rate, and student achievement differ across districts in the state of Missouri or are non-stationary. Both OLS and GWR were completed to assess the relationship between each predictor variable and student achievement. If race and other predictor variables do indeed operate differentially across space, use of GWR will demonstrate improved model fit, and illustrate the variability in these relationships.

A shapefile consisting of polygons representing school districts across the state served as the unit of analysis. A global OLS regression model and GWR model examined the relationship between each predictor variable and the composite variable for student achievement. Adaptive spatial kerning in GWR determined the best-fit local regression equations for each district based on the district location and its optimal group of nearest neighbors. The study used the Akaike Information Criterion (AIC) to determine the optimal number of nearest neighbors for each district polygon. GWR local R^2 values were mapped to visualize the strength of the relationships in the school districts across the state. Additionally, *t*-tests were completed for the beta coefficients to map the statistically significant R^2 values across districts within the state at the alpha .05 level. The Benjamini-Hochberg procedure for controlling the Type I error rate for multiple comparisons was used to determine significance levels (Thissen, Steinberg, Kuang, 2002).

Missouri has a total of 558 districts, 72 of which consist of only elementary schools; 37 comprising charter school districts; and 449, both elementary and secondary schools. While student achievement data were available for all 558 Missouri school districts, graduation and dropout data are collected only for districts with secondary schools. Consequently, when examining the relationship between student achievement and the graduation rate and dropout rate predictor variables, we removed districts consisting of only elementary schools from the analysis. DESE provided graduation rate data for 457 districts, and dropout rate data for 480 districts. Thus, OLS and GWR analyses for these two predictors includes only these school districts.

3.4 Results

Table 3.2. OLS / GWR Results

	OLS *			GWR			
	R^2	**Adjusted R^2**	**AIC**	**R^2**	**Adjusted R^2**	**AIC**	**# Neighbors**
FRPL	0.290	0.289	4028.64	0.443	0.374	3992.09	59
% Non White	0.067	0.065	4181.18	0.353	0.253	4099.49	46
Attendance Rate	0.151	0.149	3007.60	0.469	0.363	2902.86	42
>10 day Suspension	0.002	0.000	4218.75	0.135	0.097	4172.82	149
Dropout Rate	0.066	0.064	3540.92	0.330	0.254	3459.00	65
Graduation Rate	0.090	0.088	2854.11	0.382	0.295	2767.80	55

*For OLS measures N=558 for all variables except Graduation Rate (N=457) and Dropout Rate (N=480).

For all variables examined, GWR models yielded lower AIC values and higher R^2 values, where both figures serve as indicators of model fit. Table 3.2 provides R^2, adjusted R^2, and AIC values for each independent variable for both OLS and GWR analyses. Better fit models are those for variables with lower AIC values and higher R^2 values. Both overall R^2 and adjusted R^2 values are provided. Overall R^2 values indicated the proportion of variance in *achievement* that can be accounted for by each independent or predictor variable, and can range from 0.0 – 1.0. GWR provides adjusted R^2 values as well to account for the addition of predictor values in the model. This calculation normalizes the R^2 equation according to the degrees of freedom and, thus, is typically lower than the overall R^2 value. Additionally, given that the number of degrees of freedom is dependent upon the number of neighbors for each model, which may vary significantly, the adjustment in R^2 values has the potential to be quite substantial. In this analysis, we created separate models for each independent variable and, accordingly, R^2 values can be used. When comparing OLS and GWR models, models with lower AIC values, specifically those that are lower by more than 3, are deemed to be better fitting models (ESRI, 2016). Table 3.3 shows a comparison of OLS/GWR R^2 values for each predictor variable. Tables 3.4 & 3.4a show a comparison of OLS/GWR AIC values for each predictor variable.

Table 3.3. OLS / GWR R^2 Comparison

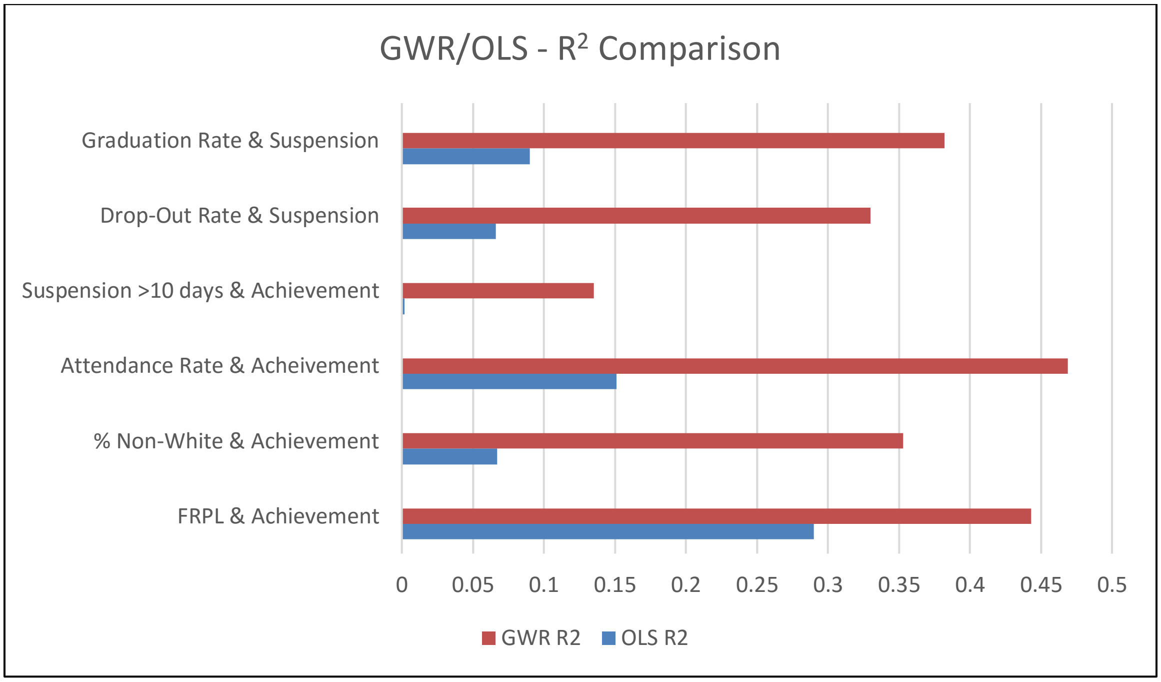
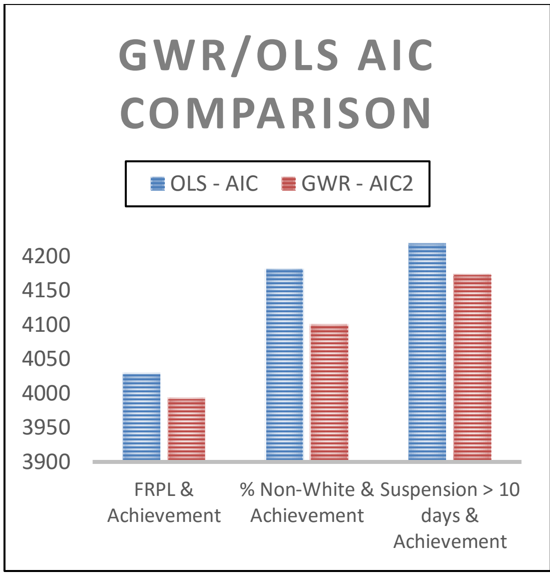
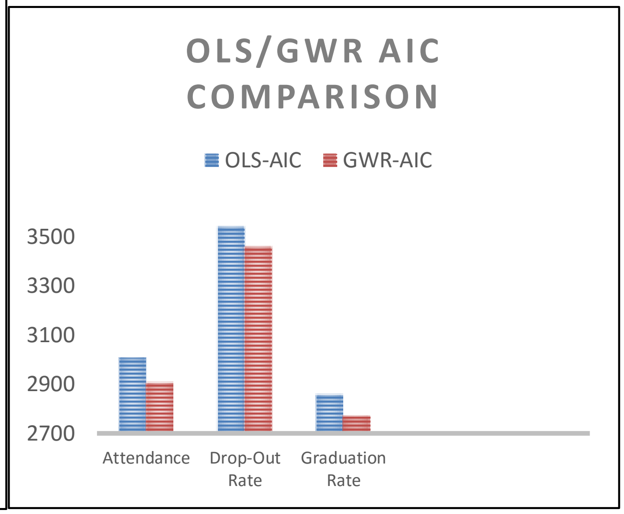
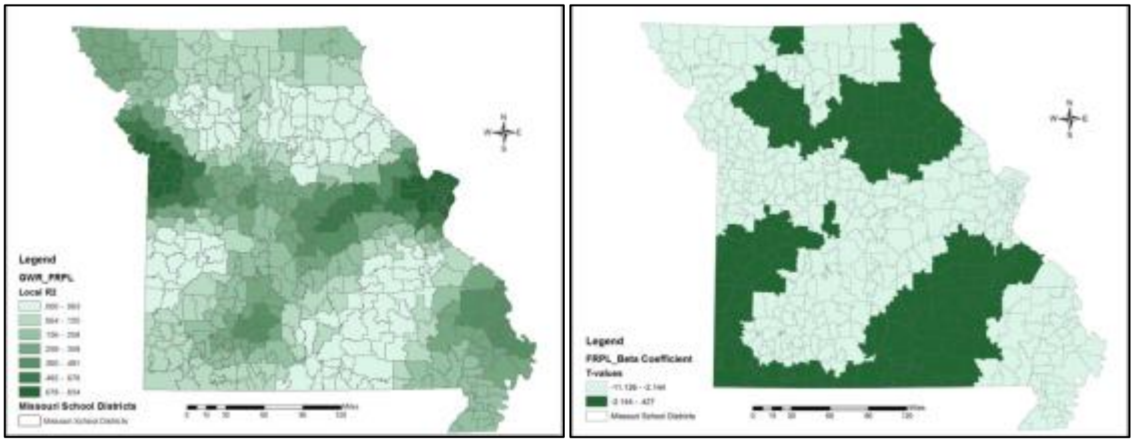


Table 3.4 (left) & 3.4a (right). OLS / GWR AIC Comparison





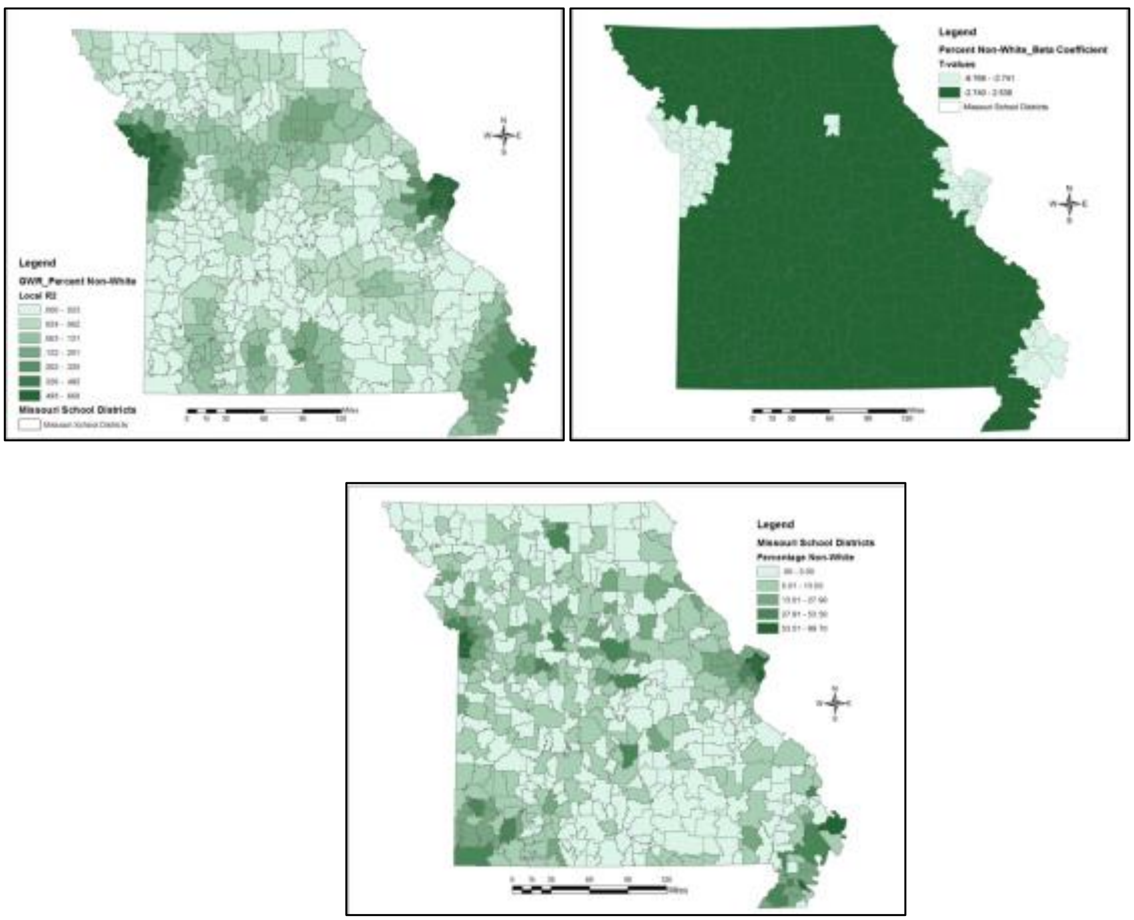
R^2 values range from 0.135 for *suspension >10 days* up to 0.443 for *FRPL* for GWR models and 0.002 for *suspension >10 days* to 0.290 for *FRPL* for OLS models. For all variable relationships examined, GWR R^2 values were higher than those for OLS models. Additionally, all AIC values for GWR models were lower indicating that local regression models are better fitting models and that the relationships examined do indeed demonstrate non-stationarity. In examining only the global model, we lose the ability to examine the geographic variability in individual relationships. The option provided in local regression models to weight relationships according to the optimal number of nearest neighbors represents additional significance. This can also be seen in Table 3.2 in the range of neighbors used to examine the variables from 42 to 149 school districts.



Figures 3.1 & 3.1a. Figure 3.1 (left) GWR showing local R^2 values for *Free and Reduced Price Lunch* and *Student Achievement* in school districts throughout Missouri. Figure 3.1a (right) Shows statistically significant beta coefficients (lighter area) for *Free and Reduced Price Lunch* and *Student Achievement* in school districts throughout Missouri.

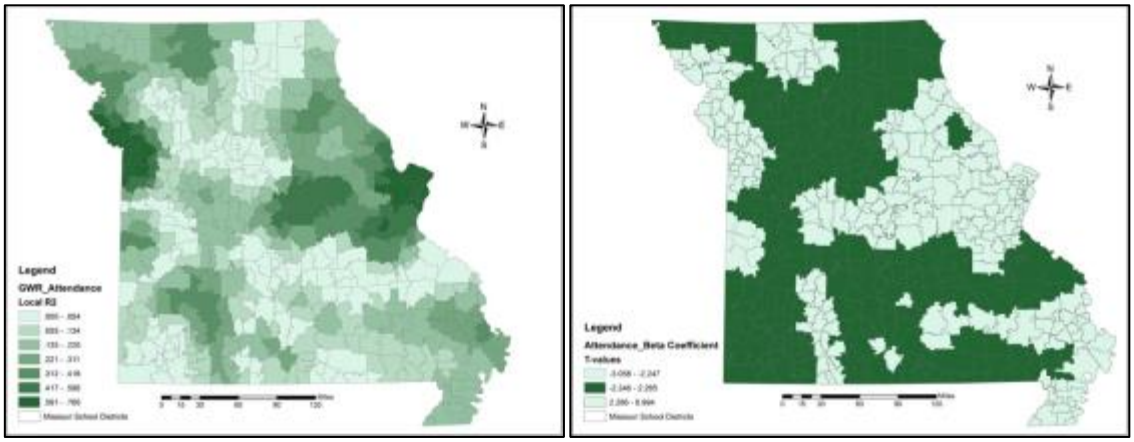
Figures 3.1 through 3.2b address our initial research questions, "What is the relationship between demographic variables, such as race and poverty, and student achievement?" and "Do these relationships vary geographically across the state of Missouri?" The overall R^2 for the GWR model was 0.443 indicating a strong relationship between poverty (measured as *FRPL)* and achievement. In Figure 3.1, we see that that this relationship between *FRPL* and student achievement varies across the state and is strongest in the two largest urban areas in the state, St. Louis and Kansas City. Local R^2 values in these two areas are higher than the overall R^2 of 0.443 for the GWR analysis, ranging from 0.679 to 0.834, indicating that poverty has a strong impact on student achievement in these areas. More rural areas in northeast and south central Missouri demonstrate the weakest relationships between these two variables with local R^2 values much lower (between 0.00 – 0.06). This analysis shows that poverty accounts for nearly half of the variance in student achievement scores overall, and as much as 67–85% of the variance in scores in the urban areas of the state which highlights the importance of the local context. Figure

3.1a shows the statistically significant R^2 values by dividing the t test values for the beta coefficients for FRPL into those that are significant and not significant at a .05 alpha level. The Benjamini-Hochberg procedure for controlling the Type I error rate for multiple comparison was used to determine significance levels. The lighter areas indicate districts with statistically significant R^2 values.



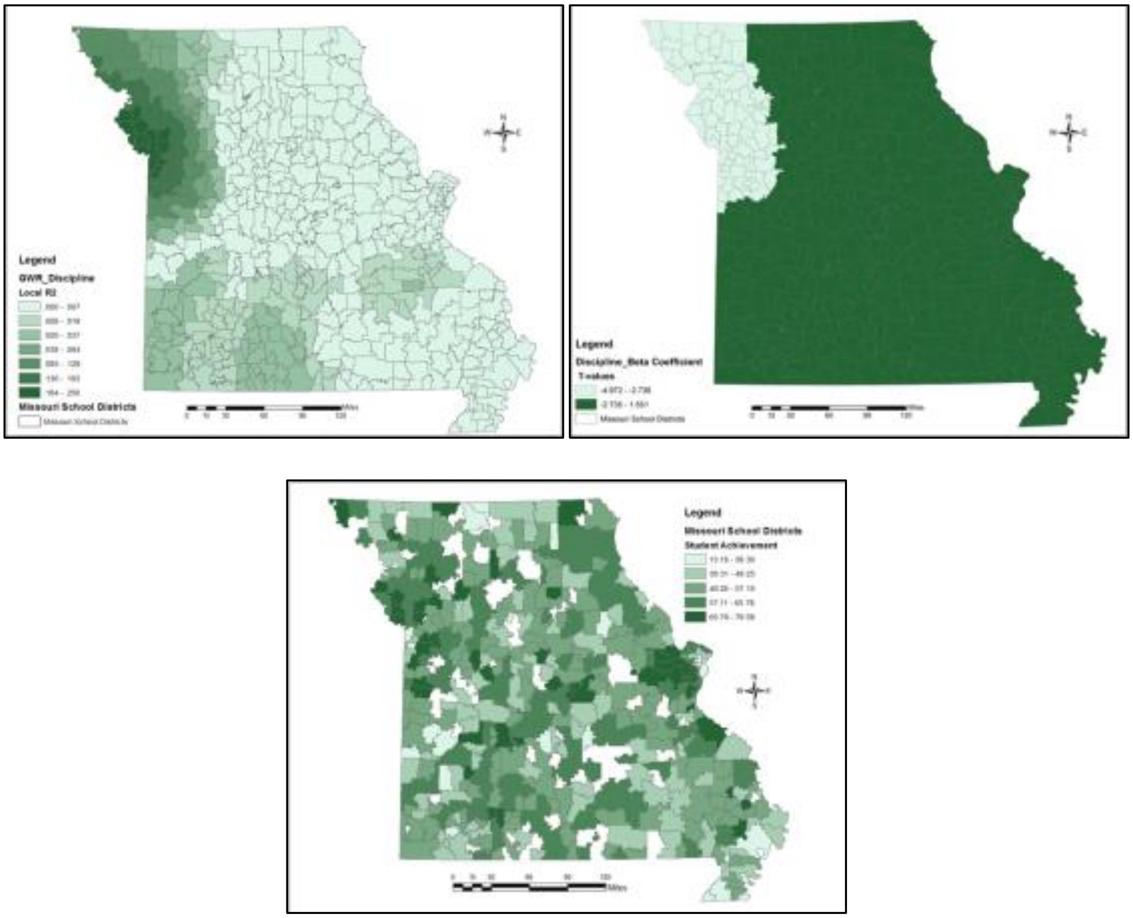
Figures 3.2, 3.2a, & 3.2b. Figure 3.2 (left) GWR shows local R^2 values for the relationship between *Percentage Non-White* and *Student Achievement*. Figure 3.2a (right) shows statistically significant beta coefficients (lighter area) for *Percent Non-White* and *Student Achievement* in school districts throughout Missouri. Figure 3.2b (bottom) shows *Percentage of Non-White* students in each Missouri School District.

Figures 3.2 and 3.2a demonstrate a slightly more striking pattern for the relationship between race and student achievement, specifically the relationship between student race as "non-White" and achievement. The overall relationship is relatively strong, with an overall R^2 of 0.353, and, similar to that of poverty, context matters as the relationship varies across the state. While the strongest relationships exist in the two largest urban areas, St. Louis and Kansas City, a moderate relationship also exists in the southeast portion of the state, or the Missouri "bootheel" region. It is important to note that the relationship is limited throughout the remainder of the state. Local R^2 values range between 0.32–0.66 in the three strongest areas, while local R^2 values don't exceed 0.12 in most districts throughout the remainder of the state. Compared to the overall R^2 value for this GWR of 0.353, race has a stronger relationship with achievement in both St. Louis and Kansas City (local R^2 values between 0.49 – 0.66) and weaker throughout the remainder of the state. Figure 3.2a showing beta coefficient t test results demonstrates a consistent pattern. Figure 3.2b demonstrates the percentage of non-white students in districts throughout the state. Consistent with these findings, the non-White student population is highest in St. Louis, Kansas City, and southeastern Missouri, whereas much less racial diversity exists throughout the remainder of the state. Central Missouri cities, including Columbia and Jefferson City, have slightly higher percentages of non-White students; however, race still seems to have smaller influence on student achievement in these two districts. This indicates that while race matters substantially in urban regions within Missouri, race has a smaller impact on achievement in more rural regions.



Figures 3.3 & 3.3a. Figure 3.3 (left) GWR showing local R^2 values for *Attendance Rate* and *Student Achievement* throughout Missouri school districts. Figure 3.3a (right) shows statistically significant beta coefficients (lighter area) for *Attendance* and *Student Achievement* in school districts throughout Missouri.

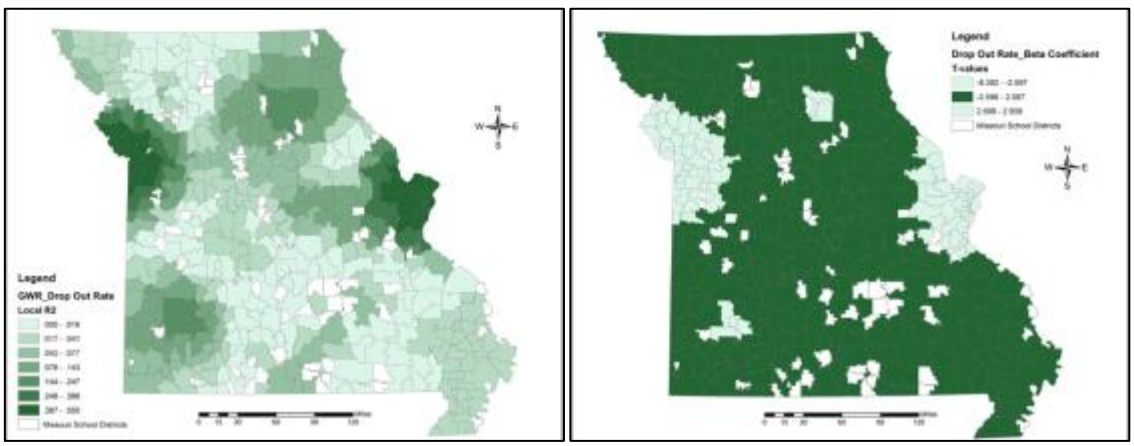
Figures 3.3 & 3.3a address our second research question, "What is the relationship between attendance rate and student achievement? Does this relationship vary geographically across the state of Missouri?" The relationship between *attendance rate* and *student achievement* demonstrates a similar pattern varying geographically throughout the state. An overall R^2 value of 0.469 is indicates an overall strong relationship between the two variables, and local R^2 values vary between .000 to .760 indicating that while in some areas *attendance* exerts limited to no impact on *achievement* scores, in other areas *attendance* exerts a very strong impact on *achievement*. R^2 values are highest in the urban centers of Kansas City and St. Louis, as well as in central Missouri. The "bootheel" region in southern Missouri also shows slightly higher R^2 values than other more rural areas of the state. Similar to other predictors model fit statistics improve with GWR and variation is seen throughout the state. T test results indicate significant beta coefficient values in these same areas (Figure 3.3a).



Figures 3.4, 3.4a, & 3.4b. Figure 3.4 (left) GWR showing local R^2 values for *Suspension (>10 consecutive days)* and *Student Achievement* throughout Missouri school districts. Figure 3.4a (right) shows statistically significant beta coefficients (lighter area) for *Suspension (>10 consecutive days)* and *Student Achievement* in school districts throughout Missouri. Figure 3.4b. (bottom) shows *student achievement* by district throughout Missouri school districts.

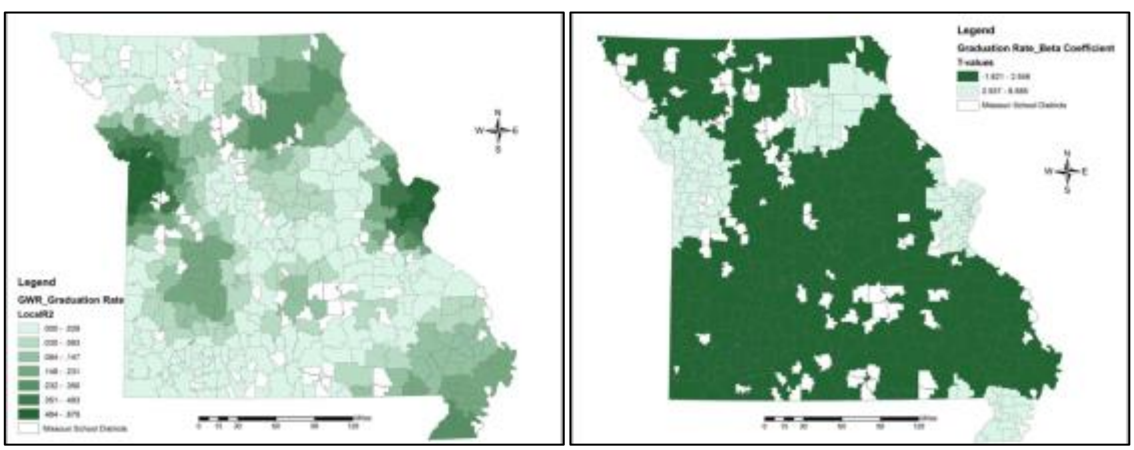
Figures 3.4 through 3.4b address our third research question, "What is the relationship between discipline and student achievement? Does this relationship vary geographically across the state of Missouri?" Figures 3.4 and 3.4a show the relationship between *discipline* (measured by *suspension for more than 10 consecutive days)* and student *achievement*. The overall R^2 value for this relationship was small at 0.135, indicating a weak relationship. Local R^2 values range between 0.00 and 0.25, and are highest in the Kansas City region ranging between 0.13 to 0.25.

Interestingly, the St. Louis region does not show a similar pattern. Beta coefficients were only statistically significant in the Kansas City and northwestern region of Missouri (see Figure 3.4a). When examined alongside student achievement scores, the lack of variability in achievement and the lower rates of achievement in St. Louis city may explain this phenomenon (see Figure 3.4b). While model fit statistics improve with GWR for this variable as well, the larger number of neighbors necessary for the analysis (N=149) and limited variation seen throughout the state are indicative of a weak overall relationship. Overall *suspensions of 10 or more consecutive days* explains little to no variance in *student achievement*.



Figures 3.5 & 3.5a. Figure 3.5 (left) GWR showing local R^2 values for *Drop-out Rate* and *Student Achievement* throughout Missouri school districts. Figure 3.5a (right) shows statistically significant beta coefficients (lighter area) for *Drop-out Rate* and *Student Achievement* in school districts throughout Missouri.

Figures 3.5 through 3.6a address the final question in this analysis, examining the relationship between district high school completion variables (dropout rate and graduation rate) and student achievement. Figures 3.5 and 3.5a demonstrate a relatively strong relationship between *dropout rates* and *student achievement* with an overall R^2 value of 0.330 and variation in local values across the state. While little variation in the more rural regions in northern and southern Missouri exists, a stronger relationship in the urban areas of Kansas City and St. Louis exists, again indicating the importance of local context. Additionally, two clusters of six to seven districts in rural areas of northeastern and southwestern Missouri demonstrate a moderate relationship between these variables with R^2 values ranging from 0.144 to 0.247. Urban areas demonstrating this stronger relationship have local R^2 values ranging from 0.387 to 0.55. Beta coefficient values are also statistically significant in these areas as well (see Figure 3.5a). Similarly, GWR for the relationship between *graduation rate* and *student achievement* demonstrated a strong relationship with variation across the state with a slightly higher overall R^2 value of 0.382. The urban areas of the state (Kansas City and St. Louis) have the highest R^2 values, and the rural areas of northeastern and southwestern Missouri as well as the "bootheel" region also demonstrate higher local R^2 values. Both drop-out and graduation rate analysis indicate that high school completion factors do demonstrate a moderately strong relationship with student achievement as well as local variation across the state.



Figures 3.6 & 3.6a. Figure 3.6 (left) GWR showing local R^2 values for *Graduation Rate* and *Student Achievement* throughout Missouri school districts. Figure 3.6a (right) shows statistically significant beta coefficients (lighter area) *Graduation Rate* and *Student Achievement* in school districts throughout Missouri.

As noted, all GWR models demonstrated improved model fit over the OLS models indicated both by higher R^2 values and lower AIC values. Those for *attendance rate, percentage non-white, dropout rate,* and *graduation rate* represented the most notable differences. The study showed improvements in the GWR model for *FRPL* and *discipline (suspension >10 days),* although they were less substantial than the other four models. These relationships are all highly dependent upon spatial context and demonstrate strong relationships in the urban areas of the state, St. Louis and Kansas City.

3.5 Lessons Learned and Directions for the Future

Missouri's history as a border south state has largely shaped its local social and political landscape. Still today demographics in Missouri's urban centers resemble those of the "South." Missouri's tense relationship with race reaches as far back as the Civil War and beyond and extends into the present with the persistent and deep impacts of stark racial housing and education segregation that continue to demonstrate effects on poor minority youth today. This case study served to examine this relationship within a larger geospatial context. More specifically, we focused on understanding the relationships between race, poverty, in-school factors, and education, and the extent to which local social environment matters.

Results of this analysis clearly suggest that relationships between demographic characteristics, in-school factors, and academic outcomes vary widely across the state. While families and students clustered within school districts and neighborhoods are more likely to share similar demographic and social characteristics, the impacts of historical conceptions of race and poverty do not adhere to these artificial boundaries. When considering these relationships, geography matters. Relationships between these demographic and in-school factors and academic outcomes exist across the state, but the strength of the relationship is largely dependent on the local geographic context.

For example, while poverty or *percentage of students receiving FRPL* and *attendance* have strong overall relationships with academic achievement as demonstrated by high R^2 values, the urban areas of the state demonstrate even stronger relationships with local R^2 values nearly twice that of the overall value. This suggests that perhaps the local context is not as homogenous in these areas as it may be in more rural portions of the state. The "Bootheel" region in southern Missouri also demonstrates a relatively strong relationship between poverty and achievement suggesting that some rural areas may also demonstrate greater heterogeneity than previously assumed. A similar pattern can be found when examining the relationship between *percentage of non-white* students and academic *achievement* as well as *graduation rate* and *achievement*, with higher local R^2 values in the "Bootheel" region and urban centers (St. Louis City and County, and Kansas City). These patterns offer an opportunity for local and regional policy to intervene on a population level to improve achievement and benefit students in these districts.

While discipline demonstrated a weak overall relationship with student achievement across the state, Kansas City demonstrated a more moderate relationship indicating that again local context matters. Although St. Louis City and St. Louis County include three of the six districts with the highest elementary school suspension rates in the nation, unlike the previous pattern, this region did not demonstrate a stronger relationship (Jones, Harris, Tate, 2015). Lower rates of achievement and limited variability in achievement in St. Louis City and County may be a factor; however, methodological concerns exist. Inconsistency in discipline policy and identification may also serve to explain the nature of this relationship. With the exception of expulsion, suspension for 10 or more consecutive days represents one of the harshest discipline policies used, and it may not be used consistently across the state, while measures such as discipline incidents may not be defined consistently in all school buildings and districts across the state. Further research into use of race and discipline indicators associated with schools and districts across the state, local interventions, as well as examination of the variance in discipline policies across the state are warranted.

Like demographic characteristics, school completion factors demonstrated a similar pattern with a moderately strong overall relationship across the state and significantly stronger relationships in the urban areas of St. Louis and Kansas City. Characteristics specific to the local contexts may be exerting a greater influence on the relationship between school completion factors and student achievement. For both school completion factors as well as discipline, research into the potential impacts of health disparities, mental health prevalence and interventions, as well as other social and political policy may shed greater light on these relationships.

Place matters. Considered alongside the political, social, and cultural history of a region, local variation exists and exerts influence on student outcomes. This case study of Missouri demonstrates this clearly. Race as defined by the social and political history of the state, as well as poverty, and other in-school factors operates differentially across the state influencing student achievement in a non-stationary fashion. Recognizing that these relationships vary across space offers an opportunity and an impetus to consider the ways in which local and regional policy may work to benefit the students most consistently impacted by these factors. Further, when conducting research on these relationships, considering methodology that allows this geographic variability is essential. In regions where local relationships may vary, global statistics may not apply. As social scientists, we must not only examine these relationships, but consider the social, political, cultural, and historical factors involved, as well as the unintended consequences that overgeneralization and failure to consider the local context may cause. Race matters differently across space.

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Chapter 4

Health, Housing, & Education: Childhood Asthma, Healthcare access, and the Urban Neighborhood in St. Louis, Missouri

> The hallmark of the emerging spatial order of the twenty-first century will be a geographic concentration of affluence and of poverty. Throughout the world, poverty will shift from a rural to an urban base; within urban areas poor people will be confined increasingly to poor neighborhoods, yielding a density of material deprivation that is historically unique and unprecedented. As poverty grows more geographically concentrated over time, its harmful by-products also will become more highly concentrated, intensifying social problems that the affluent will naturally seek to escape.
>
> (Massey, 1996, p.399)

4.1 Introduction

Douglas Massey described the growing concentration of poverty and affluence twenty years ago, and suggested that "just as poverty is concentrated spatially, anything correlated with poverty is also concentrated" (Massey, 1996, p.407). So as a geographic continuum of poverty and affluence has emerged, so too has a geographic continuum of good and poor health. Children are not immune to this structure. Patterns of disease, particularly chronic childhood disease, have emerged and disproportionately impact the most vulnerable populations. These disparities do not disappear as children age; they persist throughout the life course. Not only do "the effects of neighborhood disadvantage experienced during childhood continue to have strong impacts as individuals move into adulthood," but it is also the case that "the effect of living within severely disadvantaged communities accumulates over generations" (Sharkey, 2013, p.7). The implications of this are that not only do childhood health disparities negatively impact individuals into adulthood, but they are also inherited by the children of the next generation through the places they inhabit (Sharkey, 2013).

4.2 Background

Asthma

Asthma remains the most prevalent chronic childhood disease among minority and poor children, and especially in urban environments. National statistics find asthma prevalence among Non-Hispanic Black children to be twice that of the national average at 16%, and prevalence among poor children to be more than one and a half times that of children who are not poor at 13% (http://www.cdc.gov/vitalsigns/Asthma/, 2009; CDC National Health Statistics Report, 2011; CDC National Health Interview Survey, 2011). The prevalence and severity of asthma has continually increased over the past three decades with substantial increases among poor minority urban youth (Eggleston, Buckley, Breysse, Wills-Karp, Kleeberger, & Jaakkola, 1999). These increases coincide with the growth in the concentration of poverty, and more specifically the increases in urban poverty. Central cities and surrounding suburbs saw increases in poverty from 56% in 1970, to 72% in 1990; while non-metropolitan areas saw decreases in poverty from 44% in 1970 to 28% in 1990 (Massey, 2016). Over the past 10 to 15 years alone asthma rates among Non-Hispanic Black children have increased nearly 50% (http://www.cdc.gov/vitalsigns/Asthma/, 2009). Similarly, according to more recent research this higher prevalence of uncontrolled asthma among poor minority children living in urban areas persists, and can be evidenced by the frequency of their emergency room visits and likely underuse of medications to prevent or control symptoms (Basch, 2011; Claudio, Stingone, & Godbold, 2006). Not only do asthma attacks and exacerbations negatively impact children's well-being, ability to participate in day-to-day activities, and overall quality of life, but frequently, limited asthma awareness leaves it's 'cold-like' symptoms un- or under-diagnosed (Erwin, Carrico, Glass, & Roberts, 2010). The chronic nature of the disease suggests that it persists over a long duration (greater than three months), cannot be prevented by vaccines or cured, and often leads to hospitalization or emergency room utilization (Boice, 1998). Moreover chronic conditions such as asthma impact children's early cognitive development, social adjustment, learning, attention, relationships with others (family, teachers, and peers), risk of adolescent depression, and increases both child and family daily stress (Basch, 2011a; Boice, 1998; S. Moonie, Sterling, Figgs, & Castro, 2008).

Education & Asthma

Health and education are linked in a cyclical pattern, one impacting the other throughout the life course. Basch's (2011) suggestion that "healthy students are better learners" (p. 593) is uncontested. Children with chronic conditions such as asthma are more likely to encounter difficulty in school either via cognitive delays due directly to the condition, or indirectly through school or class absence. Asthma is the primary reason for missed days of school among youth, especially elementary school students, with children with asthma missing an estimated 15 million days per year and an average of three days more per year than those without asthma (Basch, 2011b, 2011c; Erwin et al., 2010; Krenitsky-Korn, 2011; Merkle, Wheeler, Gerald, & Taggart, 2006). A study by Krenitsky-Korn (2011) found that students with asthma missed twice as much school and had lower math and English scores as those without asthma, and felt teachers were complicit in allowing them to miss work due to asthma related absence. This study further suggests that impacts in certain subjects may pose a greater risk for students with asthma, such as math which is sequential leading to a larger cumulative effect when class time is missed (Krenitsky-Korn, 2011). Estimates suggest that for middle and high school students alone these absences lead to more than one million missed hours of instructional time and a loss of more than five million dollars in potential school funding annually (Erwin et al., 2010).

Asthma disrupts children's sleep, and impacts their memory, concentration, and ability to participate fully in school (Erwin et al., 2010; Merkle et al., 2006). Research further suggests that youth with chronic asthma also experience greater stress, which impacts their ability to concentrate at school and may result in negative social impacts (Boice, 1998). Further some medications used to treat asthma disrupt students ability to learn and attend in school (Boice, 1998). Missed school days directly leads to lost learning opportunities and may cause limited motivation in school and overall decreases to their feelings of 'school connectedness,' which encompasses interactions with teachers and peers, ability to participate in extra-curricular activities, and ideas such as trust in teachers and peers as well as potential impacts on behavior (Basch, 2011c; Krenitsky-Korn, 2011; Mohai et al., 2011; S. A. Moonie, Sterling, Figgs, & Castro, 2006; S. Moonie et al., 2008; Taras & Potts-Datema, 2005). Teachers have reported limited knowledge or awareness of asthma, and reduced expectations and goals for students with asthma (Krenitsky-Korn, 2011). Kretnitsky-Korn suggests that "patterns of increased school absenteeism are often established early in a child's academic career and may pose problems in the form of blocks to learning and engagement" (p. 61). Ultimately, these all potentially impact student academic achievement and may lead the youngest children experiencing asthma to be substantially behind as early as preschool.

Place & Asthma

We know that minority status (especially for African Americans and Puerto Ricans) and poverty have been associated with higher rates of childhood asthma (Claudio, Stingone, & Godbold, 2006). Recently, the built environment and urban locality have more frequently been associated with childhood asthma as well. While high asthma prevalence in urban areas is often associated with minority status, we know that when controlling for zip code, the relationship between race or ethnicity and asthma disappears (Basch, 2011). Moreover, research has indicated that differences in asthma rates by race cannot be explained by socioeconomic status alone (Eggleston et al., 1999). These findings suggest that factors other than race and socioeconomic status may be responsible for the substantial increases we have seen in urban asthma rates. Much of the literature regarding childhood asthma cites characteristics common in urban environments as triggers for reactions, including higher concentrations of pollutants (indoor and outdoor, stationary, land use, and mobile), higher residential density, limited green space, increases in public and low income housing, poor quality and deteriorating housing, and violent crime (Gupta et al, 2010; Cummins & Jackson, 2001, Priftis, Mantzouranis, & Anthrcopoulos, 2009; Corburn, Osleeb, & Porter, 2004, Patel et al, 2011). The presence of public housing facilities is relevant because environmental elements of public housing facilities specifically have been shown to be associated with asthma exacerbations (Eggleston et al, 1999; Hynes et al, 2003).

Scholars have examined neighborhood level characteristics of urban areas with high asthma rates. For example Corburn, Osleeb, & Porter (2004) used Geographic Information Science (GIScience) to examine the urban neighborhood effects on childhood asthma in New York City. By examining asthma prevalence and analyzing the effects of socio-demographics, housing characteristics, and stationary, land use, and mobile sources of air pollution in the area, they found positive correlations between "low socioeconomic status, percentage minority, public and inadequate housing, and multiple environmental pollution burdens" (Coburn et al, 2004). Similarly, Cummins and Jackson (2001) found associations between asthma and outdoor environmental triggers like ground–level ozone, particulate matter, and soy dust. In the last decade, researchers have identified changes in housing quality, residential density, and socioeconomic status as risk factors for increased asthma prevalence, and found associations between air pollution and frequency and severity of asthma and asthma symptoms related to place for minority children (Priftis et al, 2009; Patel et al, 2011). Other studies have found associations between violent crime and childhood asthma prevalence among students in Chicago public and parochial schools (Gupta, Zhang, Springston, Sharp, Curtis, Shalowitz, Shannon, & Weiss, 2010). Potential reasons for this include increased stress as a result of increased neighborhood crime serving as a biological trigger for asthma exacerbations and increased exposure to known asthma triggers either through adult coping behaviors such as smoking or tendency to keep children indoors in neighborhoods with higher rates of violent crime (Gupta et al, 2010). These findings provide substantial evidence supporting the importance and further examination of place, specifically urban environments, when examining chronic diseases such as asthma.

Healthcare Access

While there are studies that have examined asthma prevalence and its relationship to place or neighborhood, few have explicitly examined access to healthcare resources, such as providers and medication, within these neighborhoods. The North St. Louis Health Care Access Study conducted by Research and Evaluation Solutions, Inc. in 2008 surveyed residents and found that not only are local options for primary and specialty care limited, but residents perceive that "their access is severely hindered by their lack of insurance and money," viewing healthcare as a “luxury and not a right,” and that the facilities and services in their neighborhoods “are not equal to the services and facilities in other areas of the region” (Morrow Carter & Jackson, 2008, p.viii). Further results of this study suggested there are few locations in close proximity, those that do exist are often at capacity, and service characteristics like hours of operation and wait time often present additional challenges. Boice (1998) suggests that, “In the case of an adolescent with a chronic illness, social class may determine the level and quality of care received and ethnicity may influence the approach to treatment” (p. 934). Asthma is the third highest cause of pediatric hospitalization and results in treatment costs of nearly $3.2 billion annually for those under 18 years of age (Merkle et al., 2006). Poor minority children in urban environments disproportionately experience the impact of this acute treatment via hospitalization and emergency room visits (Merkle et al., 2006). Access to regular healthcare providers not only results in the reduction of emergency room visits for respiratory problems, but it also improves school attendance and achievement, ability to self-manage asthma, attitudes about health care and health care providers, and the overall health of children with asthma (Krenitsky-Korn, 2011). Many studies utilize hospitalization discharge data, hospitalization rates for childhood asthma, emergency room discharge data, or frequency of emergency room visits, yet fail to further examine reasons for, and impact of, increased use of hospitals and emergency rooms for primary management of pediatric asthma, including access to healthcare services and health insurance. Moreover, studies suggest that one potential explanation for the increase in urban minority asthma prevalence is the underuse of preventative and controller medications (Basch, 2011b). A potential reason for this underuse of medication may be access, and thus this warrants an examination of both physical and financial access to both physicians as well as preventative and controller medications.

The Local Context

St. Louis presents clear evidence of the trends occurring in many of the metropolitan centers across the country today. While studies exist regarding the neighborhood, housing, and other socio-demographic characteristics of urban environments with increased asthma in large urban areas like New York and Chicago (Coburn et al, 2004, Gupta et al, 2010), few such studies exist for the St. Louis, Missouri, metropolitan area. Highly segregated neighborhoods, high poverty neighborhoods, and high asthma rates are characteristic of St. Louis. At the edge of the rust belt, persistent decreases in urban population amid suburban growth and consistent increases in poverty are further evidence of these trends. These characteristics make the St. Louis metropolitan area one worthy of study. Additionally, St. Louis continues to demonstrate significant health and education disparities among its residents and in both its urban and suburban neighborhoods and school districts (Purnell et al, 2014).

The elementary and secondary education landscape in St. Louis has recently undergone substantial change with adjustments in desegregation policy as well as the loss of accreditation of multiple urban and suburban districts in the area. Highly segregated neighborhoods and schools, with substantial disparities in outcomes are areas of serious concern for regional policymakers in the areas of education, healthcare, and urban planning. Consideration of health disparities and related neighborhood characteristics offers a potential policy avenue to address these disparities and improve the opportunity structure for the region's most vulnerable populations. As such a descriptive analysis of the ecological base for the neighborhood characteristics that serve as potential risk and protective factors impacting the prevalence of chronic childhood illnesses like asthma are necessary and add substantially to the conversation regarding both health and education disparities in metropolitan centers. The purpose of this study is to identify 'hotspots' or statistically significant concentrations of high or low levels of childhood asthma prevalence within the city of St. Louis, and explore the neighborhood characteristics and access to healthcare resources within these hotspots to identify significant patterns or spatial associations. This study seeks to determine whether there are indeed ‘hot spots’ of high or low childhood asthma rates within St. Louis City at the zip code level. Further this study asks:

4. Is there a spatial relationship between asthma hotspots and neighborhood characteristics (i.e. the presence of public housing, housing quality as measured by the age of housing stock and the location and amount of condemned housing, or violent crime)?

5. Do families in these ‘hotspots’ have access to healthcare insurance, pediatricians, and controller medications?

6. Is there a spatial relationship between asthma hotspots and school attendance or academic achievement outcomes for elementary age students?

4.3 Methodology

GIS methodology is uniquely suited for a descriptive analysis such as this, as it allows us to describe, summarize, visualize and compare data, especially population level data from multiple data sources in a more meaningful way. ArcGIS 10.4.1 was used to create all maps and analyze the prevalence of childhood asthma by zip code, the presence of public housing by zip code, the quality of housing (as measured by the age of housing stock and the location and presence of condemned housing, or housing that is in ‘poor’ and ‘unlivable’ condition), the locations of pediatricians and allergy/immunology specialists, the locations of pharmacies, and school attendance and achievement. Cluster analyses were conducted using *Hot Spot Analysis*

(Getis-Ord Gi) found in the spatial statistics toolbox available within ArcGIS 10.4.1. Results were then used to examine and analyze the spatial relationships between childhood asthma prevalence, demographic characteristics, neighborhood characteristics, healthcare access, and educational outcomes. Some additional statistical analyses were conducted outside of ArcGIS using IBM SPSS Statistics 21.

4.3.1 Data Sources

Asthma Data

Population and demographic data by zip code was obtained from the 2010 United States Census. Emergency room discharge data for children under 15 years old with a diagnosis of asthma by payer source was obtained from the Missouri Department of Health and Senior Services (DHSS) – Missouri Information Community Assessment (MICA) for the most recent year of available data at the time (2010). A limitation of the use of emergency room discharges as a measure of asthma prevalence is that it may miss repeat admissions of the same patients, and thus may both over and underestimate prevalence rates for various areas. This measure does however serve as our best proxy for asthma prevalence and poorly controlled asthma, and thus is still effective and valid for these purposes.

Housing and Neighborhood Data

Locations of public housing facilities within St. Louis city were obtained from the St. Louis Housing Authority (SLHA). This agency is operated by the Department of Housing and Urban Development (HUD) and manages the public and subsidized housing within the city of St. Louis. The age of housing stock by zip code was obtained from the 2010 United States Census, American Community Survey. Locations of condemned properties throughout the City of St. Louis were obtained from the Building Division of the City of St. Louis. The St. Louis City Building Division condemns and maintains a database of each home it deems “unlivable.” The

City of St. Louis also tracks and maintains a database of crimes by type and month for each of the neighborhoods in St. Louis. A dataset for 2010 violent crimes (defined as homicides, rape, robbery, aggravated assault, and simple assault) by neighborhood was created from this database.

St. Louis is comprised of 88 different neighborhoods, 79 of which are residential and the remaining 9 are parks. These neighborhoods are the level at which St. Louis tracks crime data. For this reason, violence was measured by neighborhood, whereas other measures often tracked at the state, regional, or national level like population and health metrics were measured at the zip code level. While this inconsistency makes it more difficult to make some comparisons across datasets for specific variables, there is minimal impact on this study. Additionally, St. Louis has historically been a largely industrial area. Both functioning and abandoned industrial areas remain throughout St. Louis City. An additional data limitation in this study is that these industrial (and thus non-residential) areas were not removed for the analysis.

Healthcare Access Data

Health insurance status was obtained from MICA. Given that 84% of patients included in this study have Medicaid health insurance benefits (see Figure 11), locations for pediatricians and allergy/immunology specialists who accept Medicaid was obtained from the Department of Social Services (DSS) – Missouri Healthnet. This data was downloaded as individual physician name and location, and a dataset including locations and number of physicians at each location was created. Provider access was limited to Medicaid providers due to data availability and the patient payer source analysis. One limitation of this is that it is possible that there are additional physicians that do not accept Medicaid in the study area. It is important to note that even if that is the case, only a small percentage of the patients included here would be able to access those private physicians. Locations of pharmacies in the study area were obtained from the Missouri

Spatial Data Information Service (MSDIS). A final variable included related to healthcare access was the percentage of households without a vehicle. This data was obtained from the 2010 United States Census, American Community Survey.

Education Data

Finally, academic achievement outcome data was obtained from the Missouri Department of Elementary and Secondary Education (DESE). Attendance rates as well as Missouri Assessment Program (MAP) results for third graders in the areas of English Language Arts (ELA) and Math were obtained for all school buildings within the City of St. Louis. Locations of each of the school buildings were geocoded in ArcMap 10.4.1.

4.3.2 GIS Methods and Analysis

An initial choropleth map was created utilizing population data by zip code for the St. Louis Metropolitan Area (including both St. Louis city and County). Emergency room discharge rates for 2010 for children under 15 years of age with asthma by zip code were joined to this data to create a choropleth map of childhood asthma rates by zip code. After joining the data, childhood asthma rates per 1,000-child population were calculated by dividing the number of discharges in each zip code by the zip code child population (population under 15 years old) and multiplied by 1,000. These rates were then used to create the initial choropleth map referenced above for the entire region. Figure 4.1 demonstrates childhood asthma prevalence across the entire St. Louis Metropolitan Area; however, the primary focus here will be St. Louis City (the area on the eastern side along the river). A new layer including only St. Louis city and adjacent zip codes was created from this data. Adjacent zip codes were included to increase the accuracy of subsequent analysis by creating more data points for areas sharing boundaries with the city. Additionally, city borders do not clearly run along zip code boundaries and thus there is some overlap of the city into these adjacent zip codes. Hotspot analysis, a statistical tool within ArcGIS 10.4.1, was conducted on this map creating a separate choropleth map showing a cluster analysis of high and low asthma rates by zip code. A hotspot analysis identifies statistically significant clusters of high or low asthma rates in a given area.

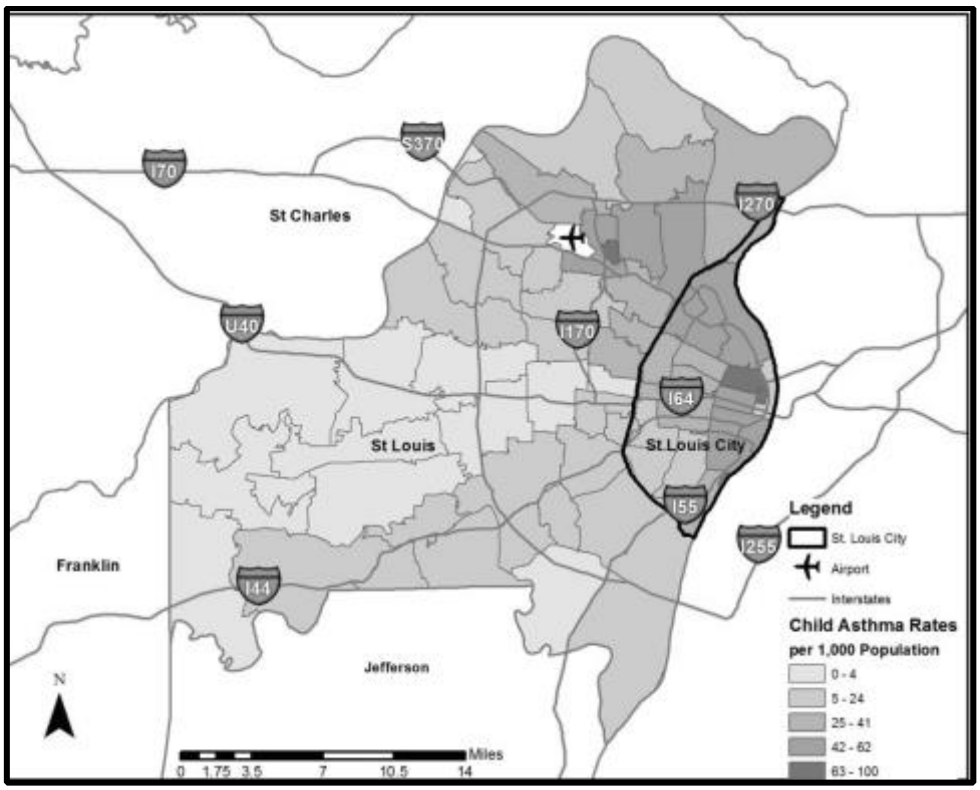


Figure 4.1: St. Louis Metropolitan Area (SLMA): Within the SLMA, St. Louis City demonstrates higher overall rates of childhood asthma (age < 15 years old).

Once ‘hotspots’ were identified (Figure 4.2), neighborhood characteristics of these areas were examined; specifically, demographics, the presence of public housing facilities, housing quality, and violent crime. Two maps were created to examine the demographics of the residents by zip code. Figure 4.3 indicates the median household income of residents by zip code, and figure 4.4 shows the percent of residents that are minorities by zip code. Locations of public housing facilities were geocoded and added to the asthma ‘hotspot’ map as point data to create a layer showing locations of public housing facilities. This map was analyzed to observe relevant patterns between public housing facilities and asthma ‘hotspots.’ Five additional maps were created to examine neighborhood characteristics (Figures 4.5 through 4.9). Three maps were created to examine housing quality, which for these purposes was defined both by age of housing stock and status of housing as condemned or “unlivable” according to the Building Division of the City of St. Louis. Age of housing stock data was added to the choropleth map of median household income and represented by a dot density plot with one dot representing 100 homes built before 1950. Additionally, a choropleth map of housing built before 1950 by zip code was created. A final housing quality map included point data for the geocoded locations of condemned properties joined to the asthma ‘hotspot’ map. Two maps were also created to examine violent crime, which for these purposes was defined as assault, homicide, rape, and robbery. Crime data for the City of St. Louis is maintained by neighborhood not by zip code. Violent crimes by neighborhood were joined as graduated symbols to the asthma ‘hotspot’ map (Figure 4.9). The size of the symbol indicates the number of violent crimes in a given neighborhood ranging from small to large. An additional choropleth map of violent crime by neighborhood was created. Hotspot analysis was conducted on this violent crime map to determine if there was significant clustering of violent crimes by neighborhood, and for comparison with the asthma ‘hotspot’ analysis (Figure 4.10).

Access to healthcare insurance was obtained from MICA data on patient payer source (see Figure 4.11). Three additional maps were created to examine healthcare access. Given that the majority of the population in question receives Medicaid and due to data availability only physicians who accept Medicaid were included. The first of the healthcare access maps included the locations of both pediatricians and allergy/immunology physicians, which were geocoded and joined to Figure 4.2 to create a map showing locations of physicians in relation to asthma 'hotspots' (see Figure 4.12). A second map was created by adding geocoded locations of pharmacies in the study area in relation to the asthma 'hotspots' (see Figure 4.13). A third and final map in this section was created to examine the percentage of households without a vehicle by zip code (see Figure 4.14).

School building locations were geocoded and added to the asthma hotspot map (Figure 4.2) to display attendance rates (Figure 4.15), and percentage of students scoring proficient or advanced on the third grade ELA and Math MAP tests for 2010 (Figures 4.16 & 4.17). Resulting maps were then examined for pattern comparison and clustering of the socio-demographic, neighborhood, healthcare access, and education characteristics with the asthma 'hotspots.'

4.4 Results

Asthma

Initial analysis of the St. Louis Metropolitan Area (SLMA) (for these purposes defined as St. Louis City and St. Louis County), revealed higher rates of asthma per 1,000 child population in the urban core or St. Louis City decreasing west throughout St. Louis County (see Figure 4.1). We know that this area is largely minority with 26% of the population living below the poverty line (US Census, 2010). Hotspot analysis conducted on the childhood asthma rates by zip code data revealed a high asthma 'hotspot,' or high clustering of high asthma rates, in a five zip code area in Northeast St. Louis City (including 63101, 63102, 63106, 63107, & 63147). A 'concentration area' showing moderate clustering of high rates of asthma was identified in a five zip code area just west and south of the 'hotspot' (including 63103, 63104, 63113, 63115, & 63118). An additional 'hotspot' for low asthma rates was identified for a five zip code area at the southwest border of St. Louis City (including 63109, 63119, 63123, 63139, & 63143 (see Figure 4.2)). Only two of the five zip codes in the low asthma 'hotspot' are in St. Louis City, the remaining three zip codes are in St. Louis County.

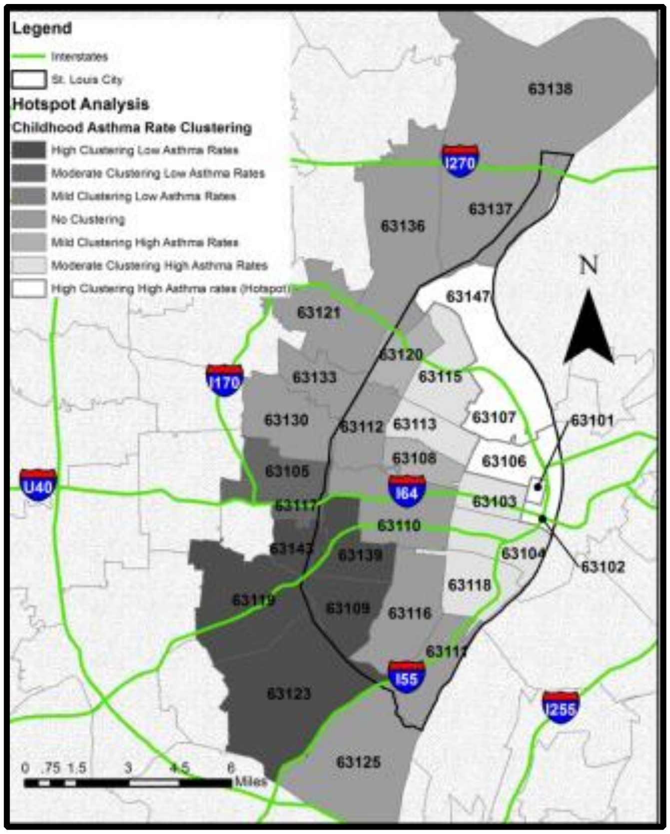


Figure 4.2: Hotspot Analysis of Childhood Asthma Rates. Hotspot analysis conducted in ArcMap 10.1 revealed a high asthma 'hotspot' including zip codes 63101, 63102, 63106, 63107, 63147 (indicated by the white area); a 'concentration area' including zip codes 63103, 63104, 63113, 63115, 63118 (indicated by the light gray area), and a 'hotspot' for low asthma rates in 2 zip codes in south St. Louis City 63109 and 63139 (indicated by the darkest gray area).

Table 4.1 demonstrates levels of clustering resulting from the hotspot analysis and average values of the corresponding demographic, neighborhood, and healthcare access variables associated with each level of clustering. This table includes both St. Louis City and the surrounding 11 St. Louis County zip codes. Over half of the 11 zip codes demonstrating no clustering (6 of the 11) and three of the five in the low asthma hotspot (demonstrating high clustering of low asthma), as well as all of the zip codes demonstrating moderate clustering of low asthma are located in St. Louis County. Clear trends in the average median household income and percentage of minority residents exist, with lower average median household incomes, and higher percentages of minority residents in areas characterized by moderate to high clustering of high asthma rates or high asthma hotspots, with the reverse in areas of high clustering of low asthma rates or low asthma hotspots.

Table 4.1. Asthma Clustering

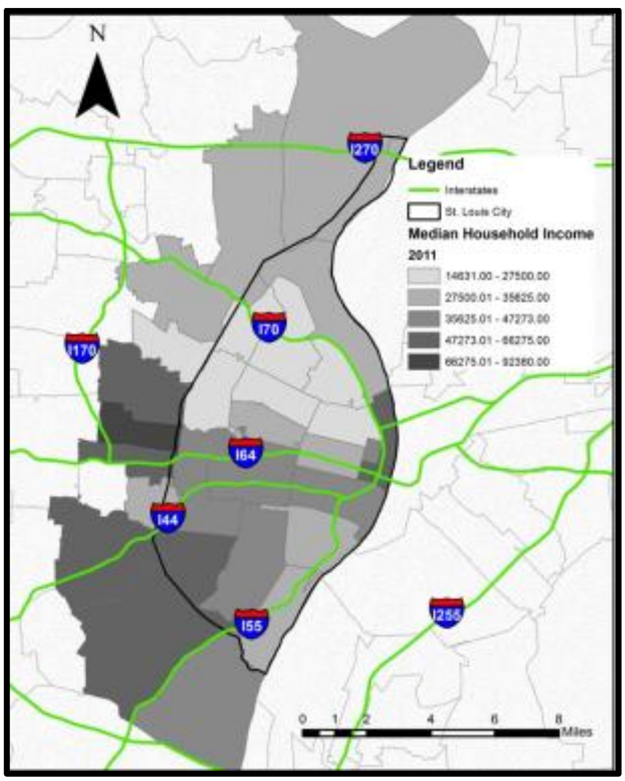
Area	# Zip codes	Population Under 15 years old	Average Childhood Asthma Rate	Average # Public Housing Facilities	Average # of Physicians	Average # of Pharmacies	Average Median HH Income	Average % Nonwhite	Average % No Vehicle
High Asthma Hotspot - High Clustering High Asthma	5	8328	56.01	2.60	0.80	1.00	34674.60	78.77	29.96
High Asthma Concentration Area - Moderate Clustering High Asthma	5	16868	44.72	3.40	1.80	3.20	30515.60	73.06	28.12
Mild Clustering High Asthma	2	3321	39.11	2.00	7.50	4.50	27898.00	71.54	25.70
No Clustering	11	57581	33.30	0.91	38.91	4.45	36282.27	62.50	16.43
Mild Clustering Low Asthma									
Moderate Clustering Low Asthma	2	3593	7.69	0.00	0.00	2.50	75600.00	19.61	4.70
Low Asthma Hotspot - High Clustering Low Asthma	5	22020	11.42	0.00	1.00	5.80	50133.60	13.88	9.26

*Note: No zip codes in the study area demonstrated mild clustering of low asthma rates.
Average figures are across zip codes in each area.

Consistent with these trends, Pearson correlation coefficients between *childhood asthma rate* and *median household income* and *percentage minority* were statistically significant (at -0.631 & 0.763 respectively, $p < .01$). The following maps further examine the spatial nature of these relationships.

Neighborhood Characteristics

Examination of neighborhood characteristics typically found in urban areas and potentially associated with childhood asthma include considering demographics (race and income), the location of public housing facilities, housing quality, and violent crime. A spatial analysis of demographic variables of residents by zip code reveals that there is stark segregation throughout the City of St Louis, by both income and race. Zip codes in the southern section of St. Louis City tend to have higher median household incomes and lower percentages of minority residents, while zip codes in the northern section of St. Louis City tend to have lower median household incomes and higher percentages of minority residents. Zip codes in the high asthma 'hotspot' and concentration area include the same zip codes with residents with the lowest median household incomes and largest minority populations.



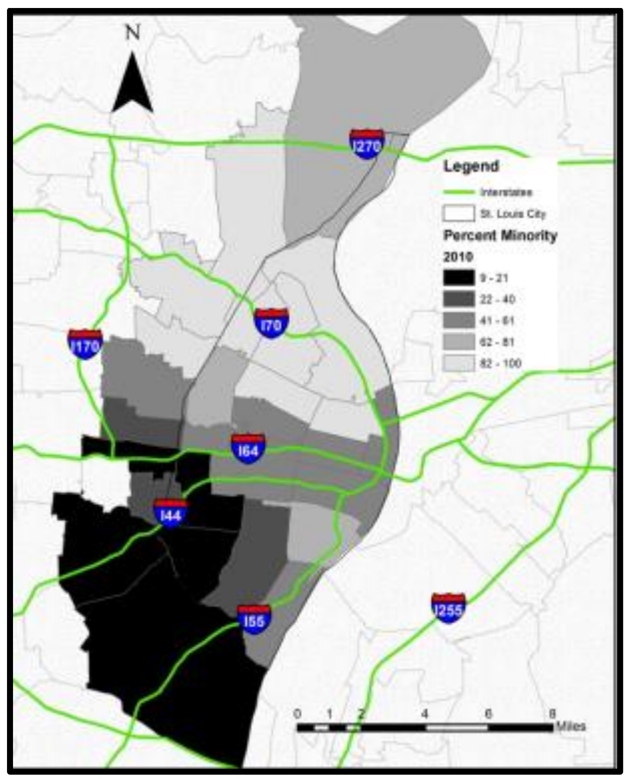


Figure 4.3 (left): The median household income of residents by zip code.
Figure 4.4 (right): The percentage of minority residents by zip code.

A spatial analysis of the locations of public housing facilities revealed that 29% of the facilities are located within the high asthma 'hotspot' and an additional 38% are located within the 'concentration area.' A total of 67% of the public housing facilities are located in areas of high asthma rates (see Figure 4.5). A single zip code in the high asthma 'hotspot', 63106, has 25% of all of the facilities within its boundaries. It is also important to note that this zip code also has the lowest life expectancy in the state of Missouri, with resident life expectancy nearly 20 years shorter than that of residents in nearby zip codes with moderate clustering of low asthma rates, higher incomes, and lower non-white populations (KSDK, 2013; Purnell et al., 2014).

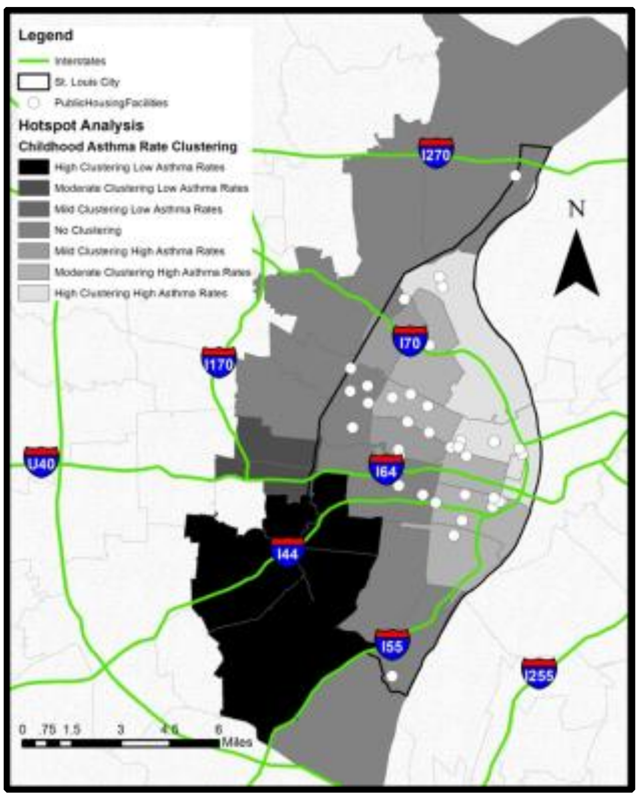
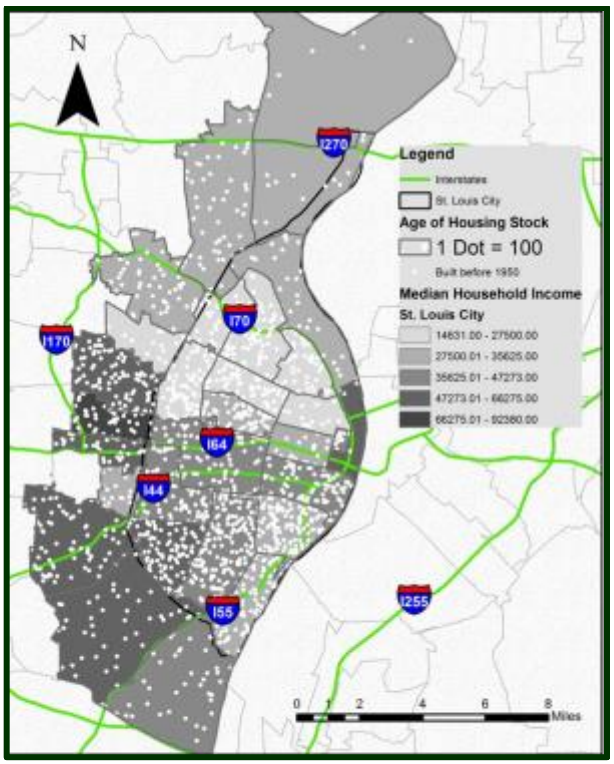


Figure 4.5: Public Housing Facilities. Environmental elements of public housing facilities have been shown to be associated with asthma exacerbations. In St. Louis City 29% of the facilities are located in the 'asthma hotspot' with an additional 38% in the 'concentration area.

As noted in the methodology, data on housing quality included both age of housing stock as provided by the 2010 Census, as well as housing deemed 'unlivable' or condemned by the City of St. Louis. Figure 4.6 demonstrates a dot density plot of the age of the housing stock of each zip code as it relates to the median household income of the zip code, with one dot representing 100 homes built before 1950 in each zip code, and the underlying choropleth map showing median household income of the zip code. Figure 4.7 indicates the age of the housing stock throughout the study area as the percentage of housing stock built before 1950 by zip code. The oldest housing in the study area is actually south with some in the concentration area for high asthma and some in areas with mild or no clustering. Additionally, some of the zip codes with older housing in the southern sections are also in zip codes with higher median household income. There are no clear patterns in the distribution of the older housing stock throughout the city, and thus no spatial associations between asthma 'hotspots' and housing stock age alone.



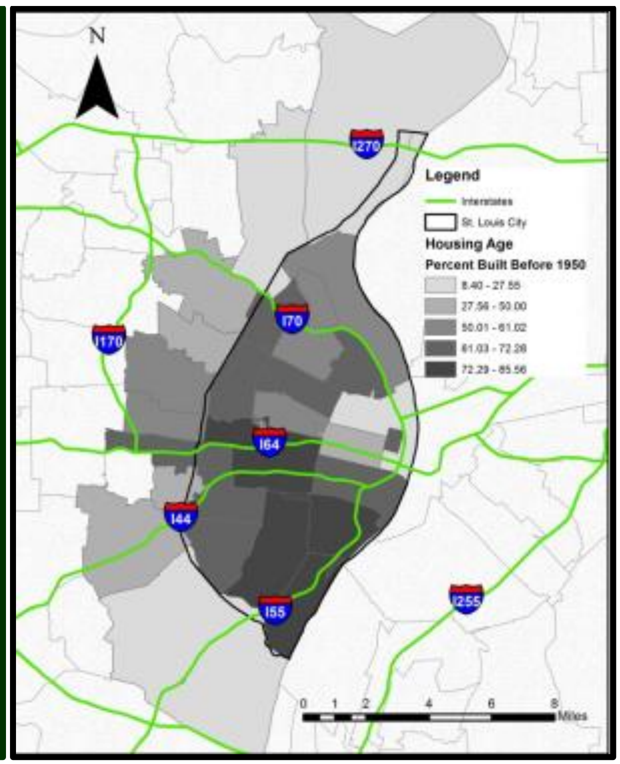


Figure 4.6 (left): A choropleth map of median household income by zip code, with a dot density plot of housing built before 1950 with 1 dot =100 homes built before 1950.
Figure 4.7 (right): Percentage of housing built before 1950 by zip code.

Consideration of housing condition is an additional indicator of housing quality. Figure 4.8 indicates the locations of condemned properties for 2010 throughout St. Louis City. It is important to note that this data might underestimate actual figures as homes condemned prior to 2010 are not included in this data, yet there may be homes that were condemned prior to 2010 and not repaired thus remaining in 'unlivable' condition throughout 2010. Figure 4.8 demonstrates clear evidence of clustering of condemned residential properties in both the high asthma 'hotspot' and concentrations areas, with fewer condemned residential properties in south St. Louis, and particularly in the low asthma 'hotspot.' Given the distribution of older homes as shown in Figure 4.7, this finding provides support for the theory that though there is a substantial number of older homes in the southern zip codes, the higher incomes of residents there may allow for better maintenance and improved conditions in those properties allowing fewer properties in those areas to be condemned.

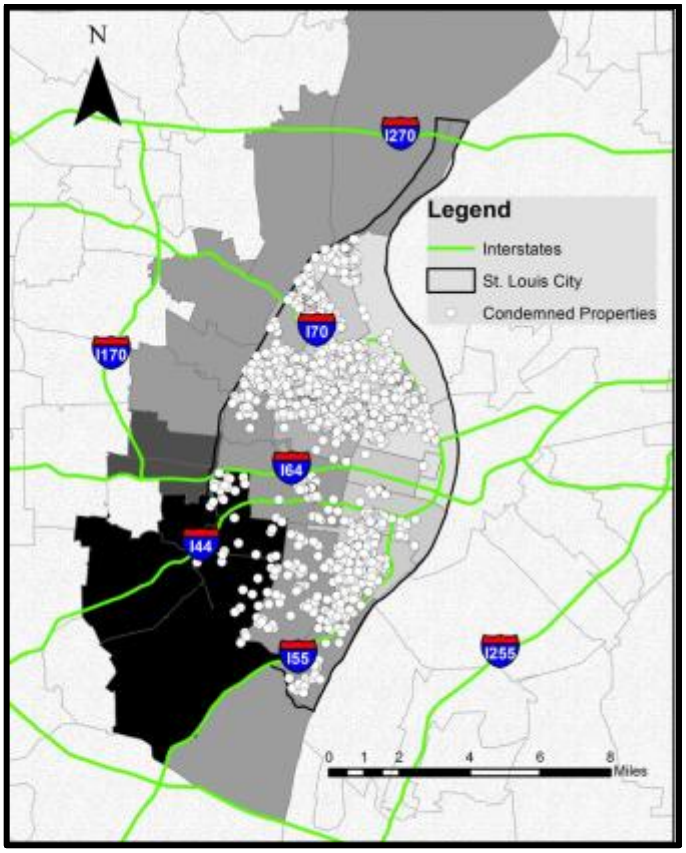
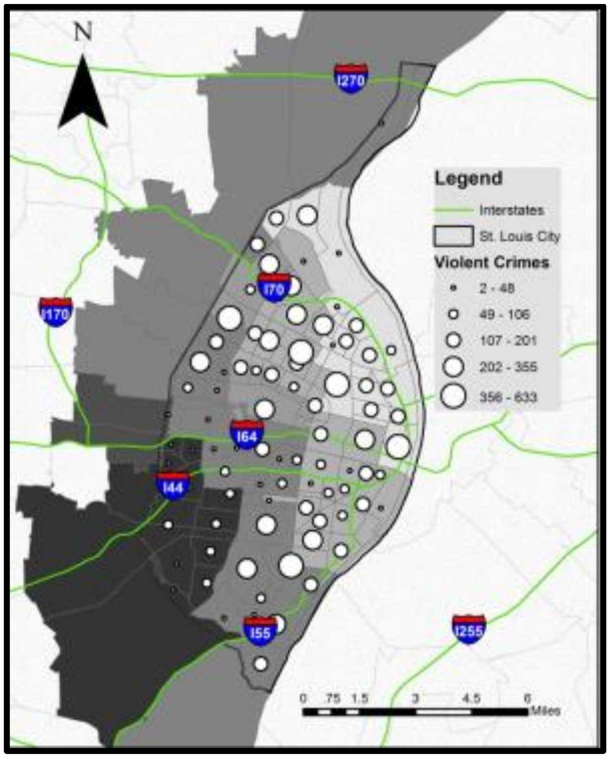


Figure 4.8: St. Louis City condemned residential properties and asthma 'hotspots.'

Violent crime was the third and final neighborhood characteristic examined in this analysis. Figure 4.9 demonstrates the number of violent crimes by neighborhood in relation to asthma 'hotspots,' where the larger symbols represent more violent crimes. There are more neighborhoods with more violent crimes in north St. Louis City neighborhoods, and specifically in the concentration area for high asthma. Violent crime hotspot analysis revealed a statistically significant clustering of violent crimes in northern St. Louis City neighborhoods and in neighborhoods that correspond to areas of high asthma (Figure 4.10). Specifically, a statistically significant high clustering of violent crimes exists within the high asthma 'hotspot' and concentration area.



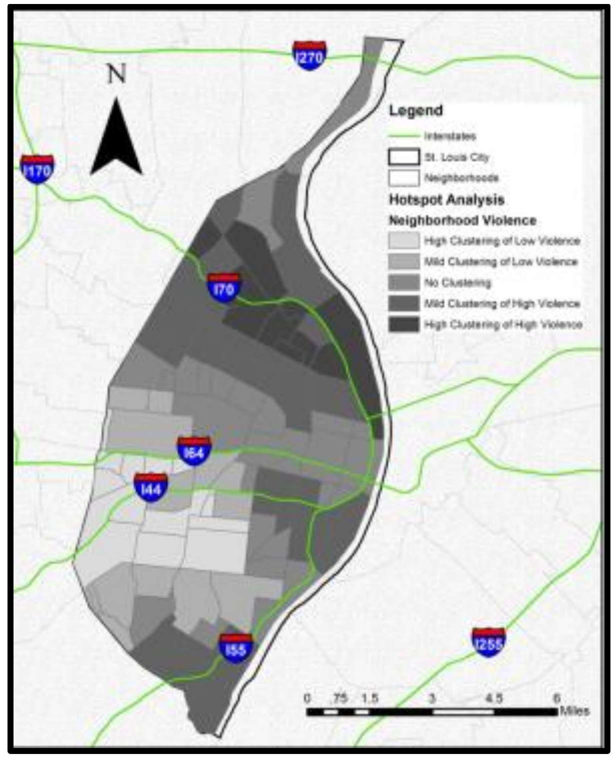


Figure 4.9 (left): Number of violent crimes by neighborhood and asthma 'hotspot' analysis.
Figure 4.10 (right): Violent crime hotspot analysis.

Healthcare Access

Health care access analysis included an initial examination of financial access to health care through health insurance. Figure 4.11 reveals payer source data for childhood asthma patients and indicates that the majority of the population has some form of health care coverage. The largest percentage receive Medicaid benefits (84%), 0.5% have other government issued insurance, 3.5% are self-pay or no charge, 11.7% have private insurance, and less than 1% reported 'other' insurance.

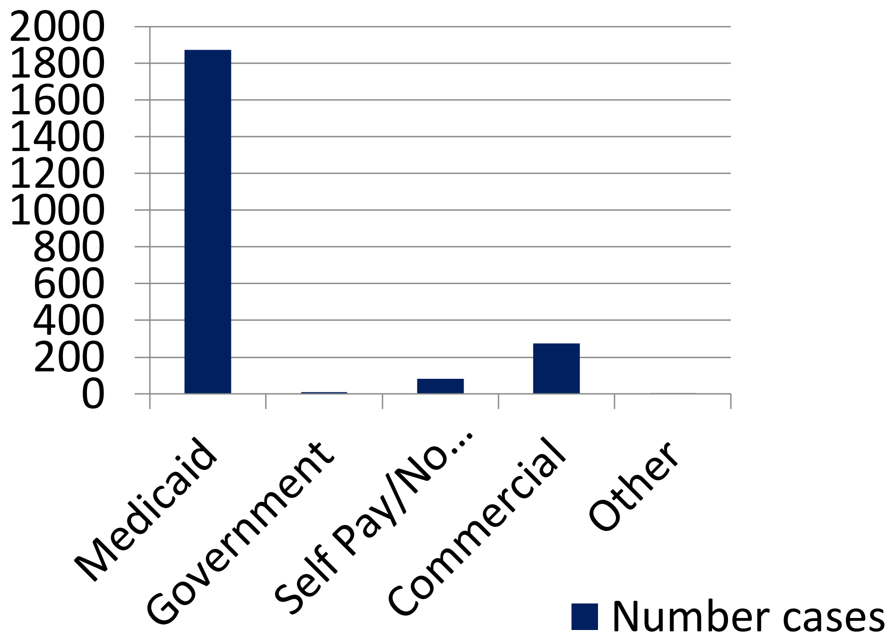
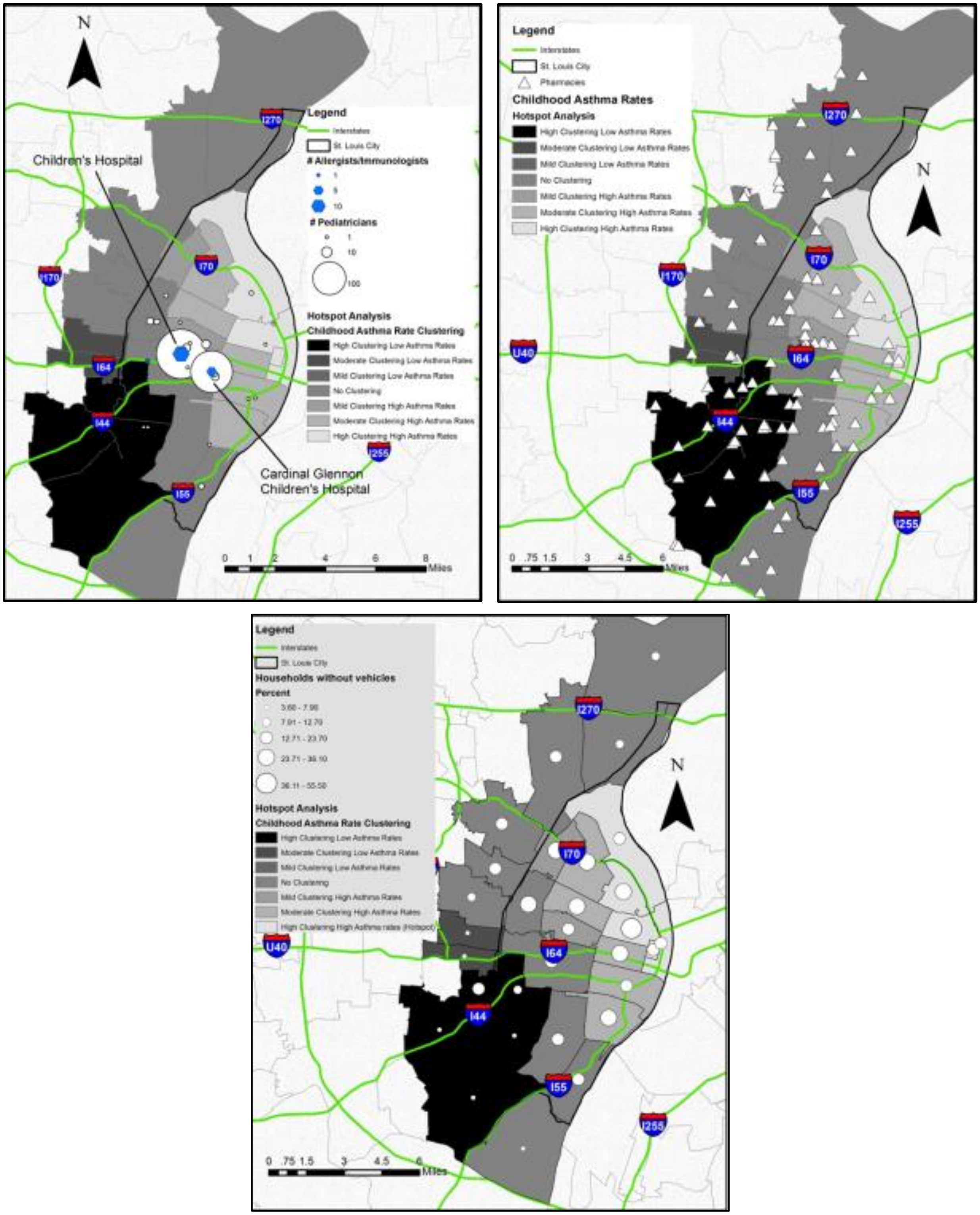


Figure 4.11: Emergency room discharge data was provided by payer source as well as zip code. Number of patients in each payer source was tallied to determine the number of patients with and without health insurance, and with differing types of insurance to indicate financial access to health insurance. Of those included in this study, 84% of the patients have Medicaid health insurance benefits and 4% were uninsured.

Given that 84% of the population has Medicaid and due to data availability, provider data was limited to providers that accept Medicaid.

Results indicated that pediatricians and allergists/immunologists are spatially concentrated in central and south St. Louis City and in areas with lower asthma rates. Additionally, the large majority of physicians included are located in or near two major hospital systems in St. Louis City. Figure 4.12 reveals that of a total of 472 Pediatricians and Allergy/Immunology specialists in St. Louis city, four or .08% are located within the high asthma ‘hotspot,’ nine or 1.9% are located in the ‘concentration area,’ and 380 or 81% are located in the two local children’s hospitals (which are in low asthma areas). A similar pattern can be seen with access to pharmacies. Figure 4.13 demonstrates that of the 153 pharmacies in the St. Louis city area five or 3.2% are located within all five zip codes in the high asthma ‘hotspot.’ In contrast, 40 pharmacies are located between seven zip codes demonstrating mild or no clustering within the city (increasing to 58 pharmacies if surrounding St. Louis County zip codes with mild or no clustering are included), and 13 pharmacies are located in the two St. Louis City zip codes in the low asthma ‘hotspot’ (increasing to 29 pharmacies if surrounding St. Louis County zip codes in the low asthma ‘hotspot’ are included). On average areas of low asthma rates or mild to no clustering have more than four times the number of pharmacies per zip code than areas of high asthma. The only two zip codes in St. Louis City with no pharmacies are in the high asthma ‘hotspot.’ Interestingly, the Pearson correlation coefficients between # of pharmacies and the percentage of minority residents was statistically significant at -.408 (at $p < .05$).

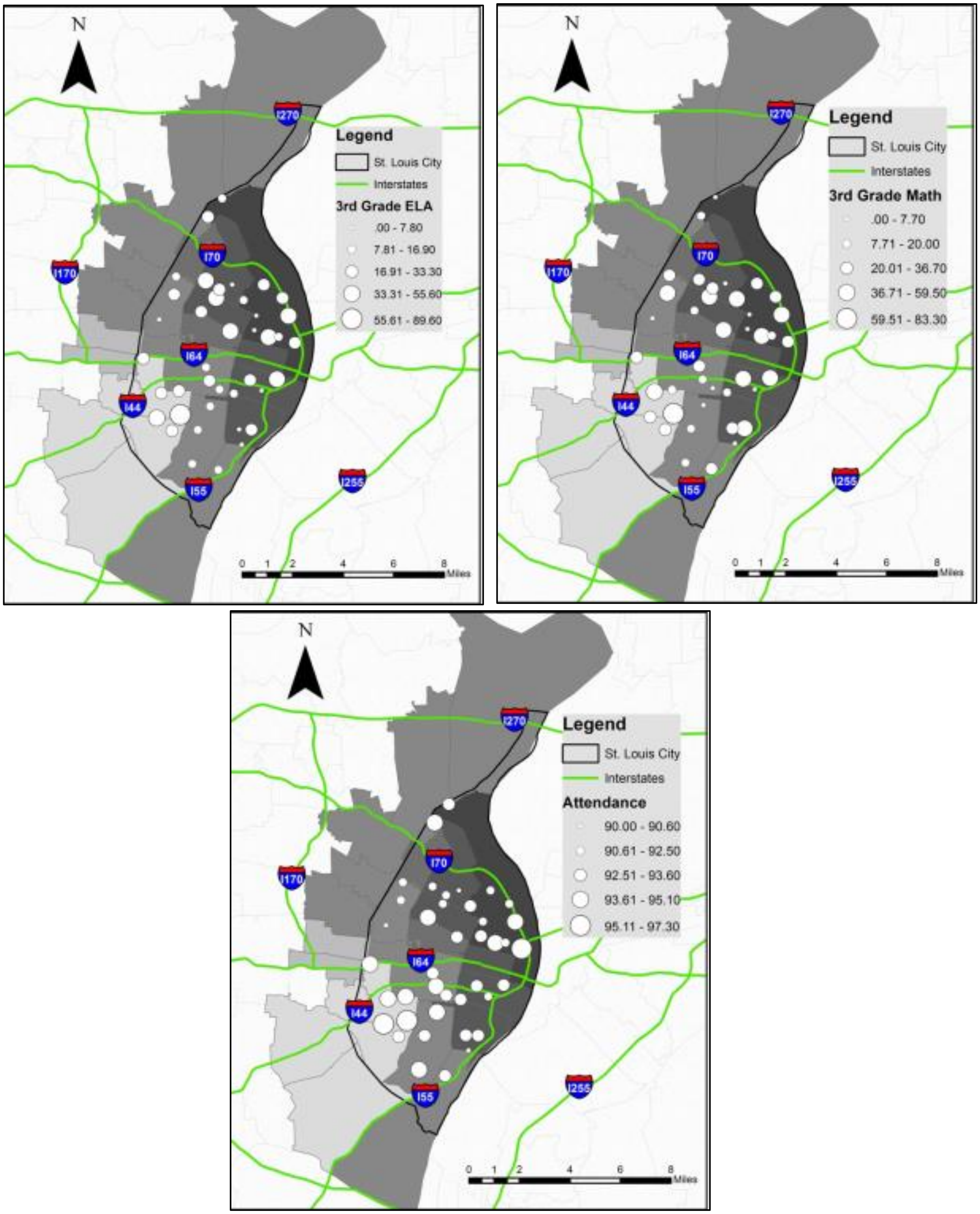
Given that residents in areas of high asthma are not located in close proximity to physicians or pharmacies, an additional map was created to examine the percentage of households in the area that do not have a vehicle and rely on rides or public transportation to visit physicians and pharmacies. Figure 4.14 illustrates the percentage of households by zip code without a vehicle. The underlying choropleth displays the asthma hotspot analysis. The high asthma hotspot has the largest percentage of households without a vehicle, with zip codes with the smallest percentages ranging from 12-24% and zip codes with the highest percentages in the hotspot ranging from 37-56%. Likewise, as many as 13-37% of households in zip codes in the high asthma concentration area do not have a vehicle. Alternatively, in most zip codes in the low asthma hotspot no more than 13% of their households do not have a vehicle, with only one zip code having more, yet still not more than 24%**.**



Figures 4.12-4.14: Figure 4.12 (left) shows locations of Pediatricians and Allergists/Immunologists and asthma hotspot analysis. Figure 4.13 (right) shows the locations of pharmacies and asthma hotspot analysis. Figure 4.14 (bottom) shows the percentage of households without a vehicle by zip code using graduated symbols and asthma hotspot analysis.

Education

Figures 4.15 through 4.17 examine educational achievement data along with the asthma hotspot analysis by school building. Figure 4.15 demonstrates the percentage of students scoring proficient or advanced on English Language Arts (ELA) MAP assessments for the third grade by school building, and Figure 4.16 demonstrates the percentage of third grade students scoring proficient or advanced on the Math MAP assessment by school building. Figure 4.17 reveals school building attendance rates. Analysis of education data did not reveal clear patterns for MAP outcome results. The low asthma hotspot was spatially associated with higher percentages of students scoring proficient or advanced in both ELA and Math, and the highest achieving school is in this low asthma hotspot as well. The high asthma hotspot and concentration area had both lower and higher achieving schools as measured by third grade ELA and Math scores. In contrast, attendance rates reveal a more consistent pattern. Several schools in the high asthma hotspot and concentration area have lower attendance rates, whereas all schools in the low asthma hotspot have higher attendance rates.



Figures 4.15-4.17: Figure 4.15 (left) shows 3rd grade ELA MAP scores for school buildings in St. Louis City and asthma hotspot analysis. Figure 4.16 (right) shows 3rd grade Math MAP scores for school buildings in St. Louis City and asthma hotspot analysis. Figure 4.17 (bottom) shows school building attendance and asthma hotspot analysis.

4.5 Discussion

As has been found in other major metropolitan areas, ‘hotspots’ or statistically significant clusters of high and low asthma rates do exist in St. Louis, Missouri. The zip codes included in the high asthma ‘hotspots’ are in areas known to have a large minority and low-income population whereas the areas with statistically significant clusters of low asthma rates have larger non-minority populations and higher median household incomes according to the US Census. St. Louis city as a whole is 48.5% African American, and 26% of the city population lives below the poverty line. Of the school age students in the St. Louis city public schools over 80% are African American. One zip code within the ‘hotspot’ in particular has the lowest life expectancy in the state of Missouri, 63106 (KSDK, 2013; Purnell et al., 2014). Similar to other metropolitan areas, just as the concentration of poverty has increased, so too has the concentration of negative health outcomes associated with poverty.

Research has shown that many elements of our urban built environment can have an impact on asthma, and childhood asthma in particular. This ranges from industrial air pollution, traffic, lack of green space, the presence of public housing, the presence of deteriorating housing, mold, nitrous oxides, inadequate ventilation equipment, cockroaches, unsanitary conditions, tobacco smoke, and so forth. Environmental elements of public housing facilities have been shown to be associated with asthma exacerbations. This analysis revealed that 29% of the facilities are located in the ‘asthma hotspot’ with an additional 38% in the ‘concentration area.’ Twenty-five percent (25%) of the public housing facilities are located in 63106, the zip code in the ‘hotspot’ with the lowest life expectancy in Missouri. Combined numbers between the ‘hotspot’ and the ‘concentration area’ indicate that 67% of St. Louis city public housing facilities are located in areas with statistically significant clustering of high asthma rates. Moreover, a clustering of condemned housing can be found in the high asthma 'hotspot' and concentration area. No spatial association was found between asthma hotspots and age of housing stock. One potential explanation for this is that residents in areas with higher incomes may be better able to maintain their older homes. Northern zip codes with lower median household incomes also have a high density of older homes, and may likewise have limited resources with which to maintain these homes. While homes built before 1950 can be found both in areas in north and south St. Louis City, a high concentration of older homes in areas of north St. Louis City with greater concentrations of residents with lower median household incomes may be indicative of poorer quality housing in these areas. Together these findings suggest that the concentration of public and low income housing, and poor quality housing in neighborhoods with residents with low median household incomes may potentially have negative impacts on the health of residents. This also supports arguments for both mixed income housing and placement of low income housing in lower poverty neighborhoods. Additionally, these findings support policy and program initiatives to assist residents in low income neighborhoods with home maintenance.

These findings support and are supported by prior research on the impact of environment and specifically public housing environments on respiratory health. Eggleston, Buckley, Breysse, Wills-Karp, Kleeberger, & Jaakkola (1999) found that "indoor exposures are more important than ambient pollutants and that bio-aerosols containing allergenic proteins are especially important" (p. 447) when considering environmental precipitants of asthma. Hynes, Brugge, Osgood, Snell, Vallarino, & Spengler (2003) examined four pilot studies in Boston public housing buildings to assess the role of indoor pollution and environmental causal factors for health disparities. The factors they examined included moisture, mold growth, inadequate ventilation, pest infestation, dust mites, the building envelope, heating systems, oxides of nitrogen, and tobacco smoke. Their findings revealed that "housing conditions that are likely to impact respiratory health negatively were common in the public housing developments" and specifically found dust mites to be a risk factor causing "susceptible children to develop asthma" (Hynes et al, 20003, p. 403). Additionally, they found asthma exacerbations due to cat, cockroach and dust mite exposure, and exposure to environmental tobacco smoke as causal factors for developing asthma in young children; as well as a strong association between fungi or molds and asthma, oxides of nitrogen and asthma, formaldehyde; and a limited association between formaldehyde and fragrances and asthma.

Gupta et al (2010) suggests that crime, specifically violent crime, is a potential socio-environmental contributor to high asthma rates among children in urban neighborhoods. A 2010 study of Chicago neighborhoods by Gupta et al found that when considering violent crime, drug trafficking and property damage, after controlling for race/ethnicity only violent crime continues to be significantly associated with childhood asthma prevalence. Similarly, the present analysis found the areas with the highest violent crime rates to be those with higher asthma rates. Specifically, zip codes within the high asthma hotspot and concentration areas had the highest rates of violent crime. A separate hotspot analysis for violent crime found hotspots, or clusters of neighborhoods with significantly higher rates of violent crime within the same area as the high asthma hotspot and concentration areas. This supports current research suggesting that violent crime may be a precipitant of childhood asthma. Paired with findings related to indoor housing conditions, this suggests a potential path through which crime may indirectly impact respiratory health. If children in areas of high violent crime spend more time in poor quality indoor environments, it is possible that the increased exposure to asthma precipitants may increase asthma prevalence in these areas. Additionally, this finding supports the need for further examination of the relationship between neighborhoods and asthma and presents a potential access point to address this chronic condition.

The health insurance access portion of this study revealed that few patients included here had no insurance (4%), and the vast majority had Medicaid (84%). This means that these children have financial access to healthcare, and yet are still choosing to utilize the emergency room for primary care and are experiencing poorly controlled asthma. The physician and pharmacy access analyses indicate that while patients may have financial access, physical proximity to physicians is limited. A large majority of physicians practice at the local children's hospitals (St. Louis Children's Hospital and Cardinal Glennon Children's Hospital), which are several miles from the high asthma hotspot and concentration area. With the substantial number of households in the high asthma hotspot and concentration area that do not have a vehicle, physical access to physicians for symptom prevention and management may be more challenging. This may lead many families to wait until symptoms are severe before accessing care. Of the remaining physician locations, many sites appear to only have one physician and few are in the north St. Louis city regions encompassing both the 'concentration area' and the 'hotspot.' This is consistent with the challenges found in the North St. Louis Health Care Access Study including facilities filled to capacity, as well as longer wait times, lower quality facilities, and limited hours of operation (Morrow Carter & Jackson, 2008, p.viii). The same is true of pharmacies. Conversely, areas with clustering of low asthma rates appear to have significantly larger numbers of physicians and pharmacies and are in closer proximity to the local children's hospitals where the majority of physicians practice. Improving healthcare access via hospital outreach, satellite offices, or other options presents a potential avenue for addressing this health disparity in the St. Louis region.

Lastly, patterns in both demographic and school attendance variables noted in this study indicate that improved healthcare may indeed be a viable path to improving student outcomes. While we know school attendance is linked to student achievement, attendance has also been linked to ideas of school connectedness, stress, and social emotional well-being which may also affect overall student success (Basch, 2011a & 2011b; Boice, 1998). Areas of higher asthma prevalence are clearly those areas with more minority students and students in poverty. Patterns in the growing concentration of poverty and affluence, good and poor health, and successful and failing schools are all the same. Further research into the causal links between these variables is clearly warranted. It is also clear that investments and interventions to improve the environments, health, and economic resources of the most vulnerable populations may indeed offer downstream benefits in improved school achievement, labor market output, earnings potential, adult health outcomes, and ultimately reinvestment in and improved outcomes for future generations.

4.6 Recommendations

Results support the need for further analysis of the presence of indoor and outdoor environmental precipitants of asthma in the asthma 'hotspot' and 'concentration area' within St. Louis city. A similar study examining both stationary and mobile sources of air pollution and childhood asthma rates may yield a more defined picture of the relationship between asthma and the built environment. Moreover, including additional census level variables such as rent level and subsidized housing (i.e. through the Housing Choice Voucher program), and coordinating data scales of neighborhood level factors such as crime may allow for a deeper analysis of the relationship between asthma and neighborhood characteristics. Further analysis of the link between asthma and education, including examination of this relationship by school type, size, and available healthcare resources would be warranted. Inclusion of additional physicians that accept private insurance (as well as those that specifically do not accept Medicaid) would be a variable for future examination as well as an examination of physical access via local public transportation options. These findings paired with known relationships between asthma and academic achievement warrant further examination, specifically the impacts of chronic childhood diseases on developmental outcomes, school or kindergarten readiness, and later academic achievement through population level studies, as well as examination of the direct impacts of asthma on achievement through case studies and individual level data collection. This analysis is descriptive in nature and formed through the compilation of multiple data sources at one cross-section of time. Coordination of multiple sets of data to clearly track these associations and potentially allow for the examination of causality would also be warranted.

Lack of healthcare access for residents of north St. Louis city indicated here supports the need for policy solutions providing for alternative methods of provision of healthcare services to address the apparent health disparity. Additionally, improving access to controller medication may be warranted. Asthma is known to be the primary reason for illness-related school absence and can be linked to lower academic achievement. Policy solutions to address this relationship and positively impact academic achievement for disadvantaged populations are further warranted by these findings. Measures like school-based health clinics attempt to address this disparity by bringing services to children in their schools, thus limiting the need for absences related to minor illness or asthma symptoms as well as improving access to preventative care and symptom management. Evaluation of current school-based health clinics, and their impact on this relationship, would inform their efficacy as a potential solution. Provided they are found to be effective, this would further support the implementation of such clinics at the elementary school level, given that those existing in this region primarily serve high schools. Coordination of housing, health, and education services may also serve as a potential policy solution. For example, sponsorship of school-based health clinics by large scale housing entities such as HUD, as well as clinics located within housing developments may serve as a points of intervention. Finally, though research says otherwise, health disparities are often linked to individual-level behaviors. Findings such as these support hypotheses considering population level determinants of health, and use of similar measures when examining disparities in education and educational achievement.

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Chapter 5

Lessons Learned and Directions for Future Research

Study 1 (Chapter 2) suggests that elements of place such as access to healthcare resources do indeed moderate the effect of asthma on assessment scores. That these impacts are seen as early as the start of formal schooling is another important finding. Additionally, this study confirmed reports in the literature indicating the impacts of living in urban areas and poverty on individual outcomes. The negative relationship between emergency room use for primary care and assessment scores, further suggests that improved access to healthcare resources may be a path to mitigating the impacts poor health has on academic outcomes. While not directly assessed here, the likelihood that other elements of place (i.e. pollution) may impact severity of disease is suggested by the findings. Further assessment of place, with more nuanced data regarding pollution and population density, is warranted.

Study 2 (Chapter 3) indicates that the impacts of the socio-economic conditions of places is non-stationary. This regional analysis revealed that even at the state level relationships between race, characteristics of place, and educational outcomes vary. A similar examination of the stationary or non-stationary nature of the relationships between health and education may prove insightful as well. These results suggest that if places themselves differ and thus impact populations and individuals differentially, then perhaps policy directed at the local level may be more effective.

The final two studies reveal that place based characteristics are indeed spatially associated with both health and education outcomes. Similar to Study 1, healthcare access is an area of importance, demonstrating a clear spatial association with health outcomes for youth. Violence demonstrated spatial patterns of importance as well, though the use of population level data for this analysis limits the interpretation and comparison of findings. While further examination is clearly warranted, this analysis provides a description of the socio-economic ecosystem that underlies health and education development and outcomes in St. Louis, Missouri. Study 3 (Chapter 4) further reveals that even on a much smaller scale, at the level of a city, these interactions vary across space. Perhaps as other scholars have suggested all impoverished areas are not alike.[11] Additional examinations of the interactions between health, place, and education in urban areas may yield further insight into the nature of these relationships.

While three studies do not determine causation, they do establish clear associations generally aligning with the bioecological model of development. The findings of these studies support theories suggesting that developmental outcomes vary as a function of exposure to places and individual's interactions within these places over time. For example, individual exposure to violent acts in their home or neighborhood demonstrated a statistically significant negative relationship with math IRT scores at kindergarten entry in study 1. In this same study, the finding that individual's ability to access healthcare serves as a moderator for the impact of asthma on early reading and math scores at kindergarten entry, suggest a potential mechanism through which proximal processes or individual's interactions with institutions in their environment (or lack thereof) impact outcomes. Studies 2 and 3 demonstrate the potential influence of geography on outcomes. Moreover, these studies illustrate the spatial associations existing between population level outcomes and characteristics of the environment or context at various levels (microsystem to exosystem). Studies that further examine the nature of these

[11] See Small, M. (2014). No Two Ghettos Are Alike. *Chronicle of Higher Education*, 60 (27), B10-B12.

relationships may more clearly illustrate the complexity of the bioecological model as it applies to the ways in which health, place, and education operate to shape individual outcomes.

A challenge to this work was the availability of individual level data for both health conditions as well as educational outcomes. These efforts were further limited by their cross sectional design, which did not allow for the examination of causation (with the exception of Study 1, which does account more clearly for time). These results do, however, deepen our understanding of the relationships and a next step would be the development and examination of potential causal pathways linking health, place, and education. Study 1 examined both a chronic and a recurrent illness. An analysis examining the impact of severity and treatment or treatment type for each illness may also be informative.

Considered as a whole, this dissertation provides great insight into the ways in which health and place interact to influence outcomes for youth. Further it suggests that the current silo-like approach to policy may continue to be ineffective. Collaborations between multiple sectors (i.e. housing, health, and education), may be necessary to make substantial improvements in any one sector. Educational institutions can and should recognize and consider health in policies directed at students and schools. Further educational institutions can and should consider geographically-based factors that impact their students, and the ways in which they serve to reproduce conditions and interactions within the spaces they inhabit. Returning to the tree analogy from Chapter 1, perhaps conditions or diseases themselves, or lack of resources alone, are not the tethers holding children back from their full potential. Perhaps it is instead the conditions of the places themselves, the point at which various aspects of disadvantage interact, that serve as the tethers that restrict the tree from growing straight and tall, thereby exacerbating the impacts of health conditions on individual outcomes.