Neighborhood Housing Intervention and Birth Outcomes in Columbus, Ohio

Thesis

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Abstract

Due to limitations in individual-based explanations of disease, neighborhoods have emerged as an essential component of public health research. Past neighborhood health studies suggest a relationship between housing and health exists. As housing plays a multitude of roles in a neighborhood, these relationships are extremely complex and have limited previous housing intervention studies.

Employing neighborhood health and political ecology frameworks, this thesis contributes to current literature by examining changes in adverse birth outcomes after a housing intervention in Columbus, Ohio's Southside neighborhood. Adverse birth outcomes, preterm birth and low birthweight, are ideal outcomes to study neighborhood effects on health, as evidence suggests neighborhood-level factors contribute to the clustering of these outcomes in disadvantaged neighborhoods. Incorporating neighborhood-level measures, I first develop a propensity score model that identifies comparison neighborhoods in Columbus, Ohio that are similar contextually to the Southside at baseline. Second, I employ difference-in-differences modeling to test whether the Southside experienced a greater decrease in adverse birth outcome relative to the identified comparison neighborhoods. Results indicate that the Southside and identified comparison neighborhoods of Columbus had similar measures of neighborhood housing structures, racial segregation, and socioeconomic conditions before the intervention. However, there were no significant differences in adverse birth outcome changes for the Southside relative to these comparison areas. As housing affects numerous health outcomes, future work could employ this comparison selection methodology in other neighborhood-level health analyses.

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CHAPTER 1: INTRODUCTION

The Kirwan Institute in Columbus stated the best "vaccine" that we can provide our children is access to stable, affordable housing (Olinger, Holley, & Reece, 2015). As the foundation of the neighborhood, housing provides more than just shelter to residents. Those who live in advantaged neighborhoods are privy to a host of benefits, including better schools, more economic opportunities, and better services or businesses. However, not everyone has the same access to a healthy home. A child's life expectancy, as well as access to educational and economic opportunities, are largely determined by their zip code at birth. Poverty and discrimination, characteristic of distressed neighborhoods, are obstacles to health equity and create neighborhoods where residents are "stuck in place" (Starkey, 2013).

Adverse birth outcomes are a public health crisis, accounting for 17% of infant deaths in 2015 (Centers for Disease Control and Prevention [CDC], n.d.). Risk of infant mortality and morbidity increase as birth weight decreases (Shapiro, McCormick, Starfield & Krischer, 1980). Affecting less educated, low-income, and minority women disproportionately, these outcomes appear to cluster in these distressed neighborhoods (Culhane & Goldenberg, 2011; McCormick, 1985; Misra, Slaughter-Acey, Giurgescu, Sealy-Jefferson, & Nowak, 2017; Parker, Schoendorf, & Kiely, 1994). Hotspots of adverse birth outcomes may result from the fact that women who are at higher risk of adverse birth outcomes live in the same area to produce these larger effects. However, the theoretical framework of neighborhood health postulates disease is the outcome from both an individual's context and composition (Kawachi and Berkman, 2003). Hotspots therefore could potentially result from additional local-level risk factors, such as lack of services, poor housing quality, and neighborhood disinvestment.

This thesis will examine whether structural improvements to an individual's neighborhood remove barriers to health equity and reduce adverse birth outcomes. Specifically, this thesis will focus on a novel investment in improved housing stock of a low-income neighborhood in Columbus, Ohio and examine whether these community-level improvements broadly impact the high proportion of negative birth outcomes in these areas.

Study Structure

This introductory chapter discusses previous research on birth outcomes and housing-related neighborhood health effects along with limitations of past studies. In this chapter, I also present my conceptual frameworks as well as my methodological approach to analysis. Chapter two is written in the form of a journal article and contains two analyses. The first integrates local-level measures of neighborhood context, over time and space, to select comparison areas for evaluation of a housing intervention. The second examines the impact of the intervention on neighborhood-level birth outcomes relative to selected comparison areas. The intended journal of publication is *Social Science & Medicine.* Chapter three concludes with a discussion of each analysis, broader impacts of the study, and directions for future research.

Research Objectives

The objective of this research is to evaluate the spillover effects, if any, from the Healthy Neighborhoods Healthy Families (HNHF) housing intervention on birth outcomes in the Southside of Columbus, Ohio. I do not evaluate the individual-level impact of improved housing on births outcomes for women living in specific houses. Rather, I take a population health perspective to examine if overall improvements in community housing impact birth outcomes throughout the population in that community. The study addresses the following questions:

1. What historical and current social, economic and political factors have led to the concentrated decline of housing and intergenerational poverty in Columbus's Southside?
2. Does investment in the affordable housing stock of a neighborhood result in spillover effects and positively impact birth outcomes in the community?

I hypothesize that investment in the affordable housing structure of a neighborhood will be associated with a decrease in adverse birth outcomes, due to reduction in maternal stress resulting from negative neighborhood effects associated with housing.

Though this research focuses on Columbus, Ohio, it has broader applications to many cities in the United States facing issues related to distressed neighborhoods and birth outcomes. In addition to providing a more complete understanding of the neighborhood effects from housing on birth outcomes, this work also develops a comparison selection methodology for utilization in other neighborhood-level spatial analyses.

Background

To study neighborhood effects of housing on birth outcomes, I focus on the Southside of Columbus in Franklin County, Ohio. Although other areas of Franklin County have high rates of adverse birth outcomes, the Southside is unique in that this area has received a sizeable neighborhood-level investment in housing after decades of abandonment. The design of the investment provides a novel longitudinal dataset. This area also has some of the highest rates of adverse birth outcomes, not only in Franklin County, but also the State of Ohio, making it an interesting case study to examine the effects of housing on birth outcomes.

Study Site: Southside, Columbus Ohio.

Consisting of portions of three zip codes (43205, 43206, and 43207) Columbus's Southside is separated from downtown by the Interstate 70 & 71 split (Figure 1). Geographically isolated by the construction of the highway system, the Southside resembles a typical central city neighborhood characterized by concentrated poverty. At the beginning of the study time period, the median household income was just over $25,000 and over half of children were living below the poverty line (ACS, 2010). Neighborhood stress was exacerbated by neighborhood abandonment through historical private market and public housing policies, along with the late 2000's Foreclosure Crisis and resulting Great Recession. Population loss due to these events fueled a surge in abandoned and dilapidated properties. At 29%, the vacancy rate for the Southside was almost three times greater than the Columbus Metropolitan Statistical Area (10.7%), 56% of mortgages were considered high cost loans, and foreclosures were double the rate for Franklin County (Figure 1) (ACS, 2010; HUD, 2007). The abandonment attracted illegal activity. Subsequently, safety was a major concern for residents, due to increases in violent crime and gang/drug activity in the neighborhood (Kelleher, Reece, & Sandel, 2018).

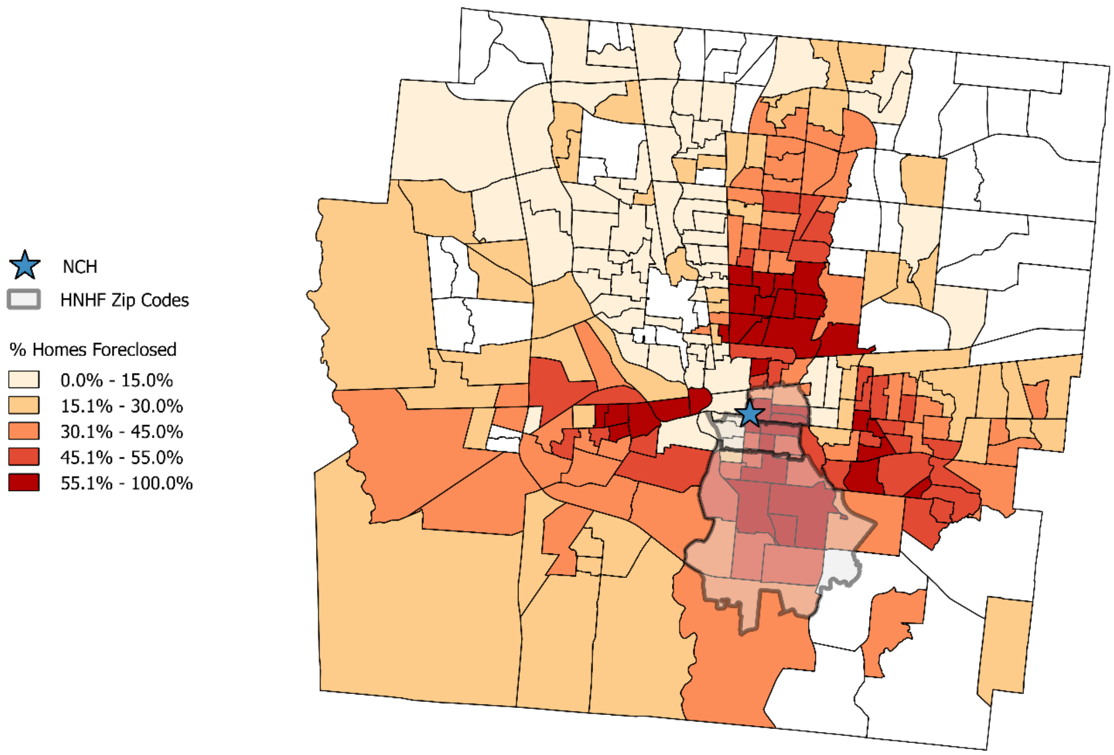

Figure 1. Percentage of Mortgages Foreclosed by Tract in Franklin County, 1/1/2007-7/1/2008 (HUD, 2007)

The main campus of Nationwide Children's Hospital (NCH), a large pediatric hospital and research institution, is also located in Columbus's Southside. As a result, families from the Southside neighborhood primarily bring their children to NCH for care. Due to their proximity to the Southside and responsibility as both an accountable care and mission driven organization, NCH began a novel intervention to treat the Southside itself as a "patient." They hypothesized that an intervention combatting structural and environmental problems in the neighborhood could reduce chronic utilizers of high-cost services, such as hospital admissions and emergency department visits. Through early exploration and community engagement, it was evident the lack of stable housing was a driving force behind neighborhood residents' high utilization of care. In

2008 as an effort to stabilize homeownership, NCH joined with Community Development for all People (CD4AP), a church already working in affordable housing, to implement a five-phase housing investment (Kelleher et al., 2018). This partnership is known as Healthy Neighborhoods Healthy Families (HNHF). Investment focused mainly on Southside's Southern Orchards neighborhood, Census Tracts 56.10 and 56.20.

Located directly south of the hospital, the vacancy rate of Southern Orchards was over 30% and foreclosures were one of the three highest in the Columbus area. Early efforts of HNHF concentrated on a Home Repair Grant Program and a Homeownership Program, which included improvement grants to current homeowners, as well as the acquisition of vacant properties for rehabilitation and sale. Properties were sold predominantly to those with incomes less than 120% area median income (AMI) to prevent displacement of current neighborhood residents. As the initiative grew programs expanded into other census tracts in the Southside, as well investment expanded to include affordable rentals, marketed towards incomes less than 80 AMI. Through a Low-Income Housing Tax Credit, a 58-unit complex called Career Gateway opened in 2017, which along with housing, provides services such as job training. Focused on rental to those working minimum-wage jobs, the development was nearly fully leased two months after opening (HUD, 2017). This demand demonstrates the need for affordable housing in the Southside. The future for HNHF includes thoughtful expansion of each program, as well as extension into other distressed neighborhoods in Columbus.

Over the last decade HNHF and their community partners have invested approximately 18 million dollars into the Southside, positively impacting over 300 properties (Kelleher et al., 2018). The work by HNHF has physically transformed the housing stock of the Southside. Vacancy rates in the area went from one of the highest in the city to less than the city average in under a decade (Kelleher et al., 2018). Quality of life has also improved. High school graduation rates have increased and although homicide rates have increased overall in Columbus, the Southside's have declined (Kelleher et al, 2018). The effort by HNHF has also attracted outside investment into the neighborhood, which has further accelerated change.

Birth Outcomes.

Burden.

Two of the leading causes of infant mortality, preterm birth (PTB), birth before 37 completed weeks of gestation, and low birthweight (LBW), babies weighing less than 2500g at birth, are significant public health crises (Centers for Disease Control and Prevention [CDC], n.d.). Although research and advances in technology have increased positive outcomes for these births, PTB and LBW rates continue to rise. The World Health Organization (WHO) estimates 12 out of 100 births occur premature, a rate which has risen 30% in the last three decades (World Health Organization, 2012). Surviving children born too early or too small are at a higher risk for lifelong issues, including, but not limited to, neurological, gastrointestinal, and respiratory problems. The associated cost with these births places an economic strain on the individual, community, and entire health care system. WHO estimated the 2005 socioeconomic expense of preterm birth in the United States alone was $26.2 billion (Howson, Kinney, & Lawn, 2012).

Risk Factors.

An abundance of research investigating PTB and LBW risk factors exists, but study results are inconsistent, as these factors are multifaceted and often interact (Misra, Guyer, & Allston, 2003). What is evident are the staggering disparities between mothers more likely to deliver PTB or LBW. Women with lower socioeconomic status are at a larger risk of an adverse birth outcome, however the largest disparity exists for those who belong to marginalized racial groups (Lieberman, Monson & Schoenbaum, 1987; Kleinman & Kessel, 1987). Accounting for prevalence differences using individual risk factors, such as income and educational attainment, neglects to fully capture the complexity of socioeconomic disadvantage (Kaufman, Cooper, and McGee, 1997). Further, disparities in individual demographic variables and socioeconomic status fail to explain the racial gap (Misra et al., 2017). Across all maternal income, age and education groups, the probability of an adverse birth outcome remains higher for Blacks relative to Whites (Goldenberg et al., 1996). These previous results indicate individual risk factors likely mediate the effects of a mother's environment on birth outcomes (Duncan, Connell, & Klebanov, 1997 & Roberts 1999).

Neighborhood Effects on Maternal Stress.

The striking differences in the neighborhoods where Black and White mothers typically reside explains racial disparities in birth outcomes (Massey & Eggers, 1990; Metcalfe, Lail, Ghali, & Sauve, 2011; Ncube, Enquobahrie, Albert, Herrick & Burke, 2016). Black mothers are significantly more likely to live in an impoverished census tract compared to White mothers (Collins & David, 1990). Zuberi et al. found majority Black neighborhoods had significantly higher levels of distress, in both socioeconomic disadvantage and abandonment, as well as higher levels of tax delinquency and violent crime, relative to where Blacks were less than a quarter of the population (Zuberi, Duck, Gradeck & Hopkinson, 2016). Property sales in majority Black neighborhoods were also a fourth of the price compared to neighborhoods where Blacks were less than a quarter of the population (Zuberi et al., 2016). Components of these distressed neighborhoods, such as violent crime and dilapidated properties, are conceptualized as stressful exposures to mothers. Through biological pathways these stressful exposures are linked to birth outcomes (Culhane & Elo, 2005). Increased stress impacts hormone and nerve producing cells, which in turn can hasten the activation of the maternal-placental-fetal endocrine systems that stimulate birth (Wadhwa et al., 2001). Maternal stress can also decrease immunity to infection, increasing susceptibility for high-risk pregnancy conditions, such as bacterial vaginitis (Culhane, Rauh, Mccollum, Elo, & Hogan, 2002). Moreover, increased stress can potentially encourage negative coping mechanisms associated with an increased risk for PTB and LBW, such as smoking or poor diet (Culhane & Elo, 2005). It is therefore vital to incorporate measures of neighborhood context into analysis of birth outcomes, in order to reduce bias and draw valid conclusions.

Neighborhood Health & Housing.

Neighborhoods and Health.

Since World War II, a significant portion of health research has focused on the biological and behavioral characteristics of individuals (Macintyre & Ellaway, 2003). However, in recent years, public health research has demonstrated these individual characteristics alone are insufficient in predicting disparate health outcomes. Place and health are intimately connected, and health outcomes are a result of both composition (who you are) and context (where you are) (Kawachi & Berkman, 2003). Individuals who are socioeconomically disadvantaged or reside in distressed neighborhoods are, on average, at greater risk for early mortality, along with a host of other diseases and conditions. Contextually, “neighborhood effects,” such as concentrated poverty, racial segregation, and low social cohesion, could account for these place-based differences in health, as well as contribute to persistent racial and ethnic health disparities (Oakes, 2004; Woolf & Braveman, 2011). As a result, both the social and physical neighborhood contexts have emerged as essential components in health outcomes research (Macintyre & Ellaway, 2003; Roux & Mair, 2010).

Neighborhood Health & Housing.

Housing remains a focal interest in neighborhood health research. The physical infrastructure of housing not only provides individuals and families necessary safety and shelter, but also facilitates important social interactions and influences identity and personal well-being of residents. Therefore, populations living in inadequate or substandard housing suffer and are at a higher risk for a host of issues (Jacobs, 2011). As the foundation of both the social and physical fabric of neighborhoods, housing influences health, including birth outcomes, through four major pathways: physical quality, location, stability and affordability.

Physical Quality Pathway.

A multitude of poor physical housing conditions have proven associations with preventable health outcomes including but not limited to, respiratory issues, infectious diseases, chronic conditions, lead poisoning, injuries, and mental health (Krieger & Higgins, 2002). Residential exposures, such as pest infestations or dirty carpets, are believed to account for approximately 40% of diagnosed asthma in children (Lanphear, Aligne, Auinger, Weitzman & Byred, 2001; Lanphear, Kahn, Berger, Auinger, Bortnick, & Nahhas, 2001). Outdated heating, ventilation, and air conditioning (HVAC) systems increase risk for cardiovascular health, headaches, nasal congestion, fatigue and skin conditions, especially for vulnerable populations (Mendell, Lei-Gomez, Mirer, Seppnen & Brunner, 2008; Saeki, Obayashi, & Kurumatani, 2015). Lack of safety devices or unsafe living conditions increase the risk for injuries, while overcrowding contributes to increased psychological distress, physical illness, and infectious diseases (Evans, 2006; Shaw, 2004). Often, these conditions coexist in homes, placing residents at risk for multiple health problems (Braverman, Dekker, Egerter, Sadegh-Nobari, & Pollack, 2011). Further, when individuals are treated only for symptoms of their health conditions, and return to the home environment, there is a high likelihood of reoccurrence.

Physical deterioration of housing also negatively affects neighborhood-level well-being, physical, and mental health. Properties that sit vacant, vandalized, or boarded up have proven associations with a decrease in mental health (Evans, Wells, Chan & Saltzman, 2000). Urban decay, following the broken windows theory, attracts criminal activity to neighborhoods where vacant and boarded-up properties are prominent (Wilson & Kelling, 1998). In a 2013 survey, when asked about vacant land in their neighborhood, residents described a loss of control over neighborhood life, fractured neighbor ties, concern for crime and safety, increased depression and anxiety, and a negative financial strain (Garvin, Branas, Keddem, Sellman, & Cannuscio, 2013).

These features of the physical housing environment have proven associations with increased risk for earlier deliveries (Farley, Mason, Rice, & Habel, 2006; Reagan & Salsberry, 2005). Mothers who live in substandard housing are at a higher risk for environmental hazards, decreased quality of life, and increased infectious disease transmissions (Grady, 2016). A study by Miranda et al found that even after model adjustment, housing damage remained significantly associated with adverse birth outcomes (Miranda, Messer, & Kroeger, 2012). Physical measures related to housing are thus important covariates in birth outcomes research.

Neighborhood Location Pathway.

Most real estate agents will argue that location is a home's most important characteristic. Residence in an advantaged neighborhood provides conditions and opportunities that can induce advantageous effects on health and health promoting behaviors (Williams & Collins, 2001). These neighborhoods provide top-performing schools, healthy food options, and safe and health promoting spaces, as well as access to employment, social services, and quality transportation. Additionally, these neighborhoods tend to have strong social ties and high collective efficacy, which reduce crime and violence and increase political bargaining. Racial barriers exist, however, in residential choice and social mobility.

Due to discrimination and prejudice, racial segregation has existed in the United States since the emancipation of slaves in the late 19^{th} Century and was also fueled by other historical events such as The Great Migration, real estate practices of racial steering and block busting, and public policies including redlining and public housing. These policies disproportionately limited Blacks from living in certain neighborhoods, forcing their residence in less desirable areas. Research indicates neighborhood disadvantage is strongly correlated with the geographic isolation of Black residents (Sampson, Morenoff, & Gannon-Rowley, 2002; Williams & Collins, 2001). The outmigration from neighborhoods of wealthier predominantly White residents reduces the urban tax base, resulting in disinvestment in social and economic resources for the neighborhood. Social capital, which includes networks, norms, and trust of social life, is generally low in disadvantaged neighborhoods (Wilson, 1991). Collective efficacy, or the shared willingness among residents to intervene to maintain social order in the neighborhood, is therefore quite low as a result (Sampson, Morenoff, & Earls, 1999). Further, relative to their more advantaged peers, poorer individuals and those belonging to more marginalized groups generally lack political influence to oppose these changes (Williams & Collins, 2001). As a result, urban infrastructure, physical environment, and overall quality of life decline in racially segregated neighborhoods. (Alba & Logan 1993; Bullard, 1994). The resulting concentration of poverty, increasing disparities in access to schools, jobs, and healthcare, as well as increases in crime, are the source of many negative health outcomes and not necessarily segregation itself (Williams & Collins, 2001).

Residential segregation has long been a variable of interest in birth outcomes analysis. Studies have demonstrated that Black women who live in residentially segregated and isolated areas have higher rates of adverse birth outcomes (Anthopolos, Kaufman, Messer & Miranda, 2014; Bel, Zimmerman, Almgren, Mayer & Huebner, 2006; Britton & Shin, 2013; Ellen, 2010; Grady, 2006; Kramer, Cooper, Drews-Botsch, Waller, & Hogue, 2010; Magerison-Zilko, Perez-Patron, & Cubbins, 2017; Osypuk & Acevedo Garcia, 2008; Walton, 2009). Segregation also increases the likelihood of adverse birth outcomes as it limits mothers' access to important social and health resources, as well as economic or educational opportunities (Grady & McLafferty, 2007).

Stability Pathway.

Residential instability is a driver of social inequality and disparate health outcomes (Desmond & Perkins, 2015). The term encompasses many challenges, such as moving frequently, falling behind on rent or mortgage, and overcrowding (Kushel, Gupta, Gee, & Haas, 2006). Further, it creates instability in other aspects of life, disrupting employment, social networks, education and receipt of social service benefits (Desmond, 2016). Often, the nature of forced moves is cyclical, as it compels residents to select substandard housing in less than ideal neighborhoods, increasing the likelihood of future moves (Desmond, Gershenson, & Kiviat. 2015). Stress and related adverse health outcomes from these factors of residential instability have a negative effect on residents. A 2012 study found individuals who experienced housing instability, were late on rent payments, were foreclosed, or were homeless experienced more anxiety attacks and depression than those who did not (Burgard, Seefeldt, & Zelner, 2012).

These stressors can disproportionately affect those with dependent children. In a study of mothers, those who experienced eviction reported higher levels of depression, worse health outcomes for themselves and their children, as well as more parental stress (Desmond & Kimbro, 2016). Housing instability is also a severe stressor during pregnancy. Mothers who moved more than twice a year while pregnant had infants with significantly of lower birth weights, compared to mothers that did not move during pregnancy (Carrion et al., 2014).

Affordability Pathway.

The nation's present housing issues are considerably different than in previous decades. Contemporary housing need has evolved from physical to financial problems, where the most pressing national housing issue is cost-burden. A large percentage of lower-income individuals and families are paying above the 30% income standard used by the federal government and increasingly face difficulties in securing available, adequate, and affordable housing. In 2011, one-third of all homeowners and half of renters spent more than this benchmark on housing (Schwartz, 2015). When a greater percentage of income is spent on housing, less is devoted to other vital needs. For example, affordably housed families spend nearly five-times as much on health care and a third more on food compared with severely cost-burdened households (Joint Center for Housing Studies [JCHS], 2017). Black women who lacked resources to meet non-essential needs had a two times risk of PTB after adjusting for psychosocial factors (Misra, Strobino & Trabert, 2010). Financially strained residents must also make important decisions on how to spend their income and are more likely to postpone needed treatment or care (Harkness & Newman, 2005).

Homeownership is the single greatest expenditure and significant source of wealth for Americans (Braverman, Dekker, Egerter, Sadegh-Nobari, & Pollack, 2011). Positive impacts of homeownership include greater stability and decreased psychological stress relative to renters (Cairney & Boyle, 2004). However, barriers exist in access to homeownership. Promising access to the "American Dream," predatory lending practices and subprime mortgage market in the early 2000's disproportionately targeted minority neighborhoods for high-cost high-risk loans (Barwick, 2009). When the market crumbled during the 2008 Foreclosure crisis, sometimes whole blocks were forced into foreclosure, and with their loss of stability, they saw a significant loss of equity as well. In 2006, Chicago properties within one-eighth mile of a new foreclosure in moderate to low-income neighborhoods experienced a 1.0 % greater decrease in value, relative to properties in high-income neighborhoods (Immergluck & Smith, 2006). Wariness of homeownership and restriction in lending from the crisis has led to an increase in the renter population, which has surged demand for affordable housing. Over the past few decades, public housing authorities have moved away from publicly-owned housing towards voucher-based systems, which are used in the private sector (Schwartz, 2015). However, for these low-income renters there is more demand than supply. Over 9 million residents compete for only 3 million affordable units (Kushel et al., 2006). Many residents are forced to settle for too expensive or substandard living conditions. Expensive rent has also been linked with adverse birth outcomes. In studies spanning almost two decades, women who paid higher median rents were at an increased risk for both LBW and PTB (Meng, Thompson, & Hall, 2013; Roberts, 1997).

Limitations of Previous Research.

In birth outcomes research, studies examining neighborhood effects are limited substantially and methodologically (Zuberi et al., 2016). The limited previous research has also suffered from a lack of strong hypotheses regarding neighborhood effects on birth outcomes (O'Campo, 2003). Further, few studies have incorporated measures of the built environment, specifically neighborhood distress variables, when analyzing birth outcomes (Giurgescu, Zenk, Dancy, Park, Dieber, & Block, 2012; Miranda et al., 2012; Zuberi et al., 2016). Studies that have examined neighborhood distress and birth outcomes focus heavily on readily available census-based neighborhood characteristics. Local measures of neighborhood context are often missing from neighborhood analysis (Zuberi et al., 2016). These measures are important components, which incorporate social stratification and inequalities into analysis for a deeper understanding of how neighborhoods affect health (Chitewere, Shim, Barker, & Yen, 2017). Methodologically, greater emphasis on the utilization of geospatial technologies is also needed, as they provide the ability to integrate and analyze multiple datasets within and across time and place (Grady, 2011). Previous neighborhood health research has also heavily relied on cross sectional studies. To establish causation, longitudinal experiments designed specifically to study neighborhood effects on health are needed (O'Campo, 2003; Roux, 2001). Throughout this literature review, I could not identify any studies that incorporated local and census-based neighborhood contexts in propensity score modeling to identify a comparison neighborhood for an evaluation of such experiments.

Research Approach.

Theoretical Framework.

This analysis is guided by merging of two theoretical frameworks, neighborhood health and political ecology, which can both be situated within the framework of disease ecology. Disease ecology posits that diseases are the result of interactions between populations, environments, and behavior (Meade, 1977). Population factors include biological and demographic aspects of a population. Environmental context consists of both natural, social and physical elements of an individual's environment. Finally, behavior includes the social structures and systems, norms and values of a place, which all influence society. When the dynamic equilibrium of these three conditions are disturbed, health is compromised.

Neighborhood Health.

The neighborhood health theoretical framework postulates health disparities are patterned by both contextual and compositional factors (Kawachi and Berkman, 2003). This framework is easily incorporated into disease ecology. Contextual factors are the result of the environment and behaviors, while compositional factors are the result of populations and behaviors, which all exist in a place (neighborhood) at a certain time.

Challenges in incorporating neighborhoods in health research include the complex feedback loops and mechanisms by which an individual's residential environment affects their health (Roux & Mair, 2010). Also challenging are alternative neighborhood boundary definitions can lead to conflicting results and conclusions, due to the modifiable areal unit problem and geographic context uncertainty (Duncan, Regan, & Chaix, 2018). Neighborhood health research advances the disease ecology framework by providing methodological tools for defining neighborhoods and examining neighborhood effects. However, the construct of the context and composition of a neighborhood itself is an important component of analysis.

Neighborhood Political Ecology.

Political ecology is a useful theoretical lens to address gaps in neighborhood health research, as it integrates policy and politics into the human-environment interaction for a deeper understanding of how place influences health (Mayer, 1996). Past research in health geography has focused primarily on proximate and intermediate risk factors (Hanchette, 2008). In birth outcomes research, "proximate-tier" risk factors could consist of biomedical conditions, such as a mother's age or a previous preterm delivery. The "intermediate-tier" incorporates behavior or personal environmental elements, such as smoking status or prenatal care utilization. "Ultimate-tier" risk factors, which incorporate high-level social, economic, and cultural processes, are seldom included in research, although many contribute to health disparities (Hanchette, 2008). Incorporating these high-level processes in analyses can identify social, economic, and historical constructs of neighborhoods, which are useful for understanding how and why neighborhood inequality and disadvantage are produced and persist (Chitewere et al., 2017).

Neighborhood Political Ecology of Birth Outcomes.

Figure 2 demonstrates the application of the neighborhood political ecology in birth outcomes research. Known risk factors for adverse birth outcomes fit into the population, behavior, and environment components of a neighborhood, which interact with each other.

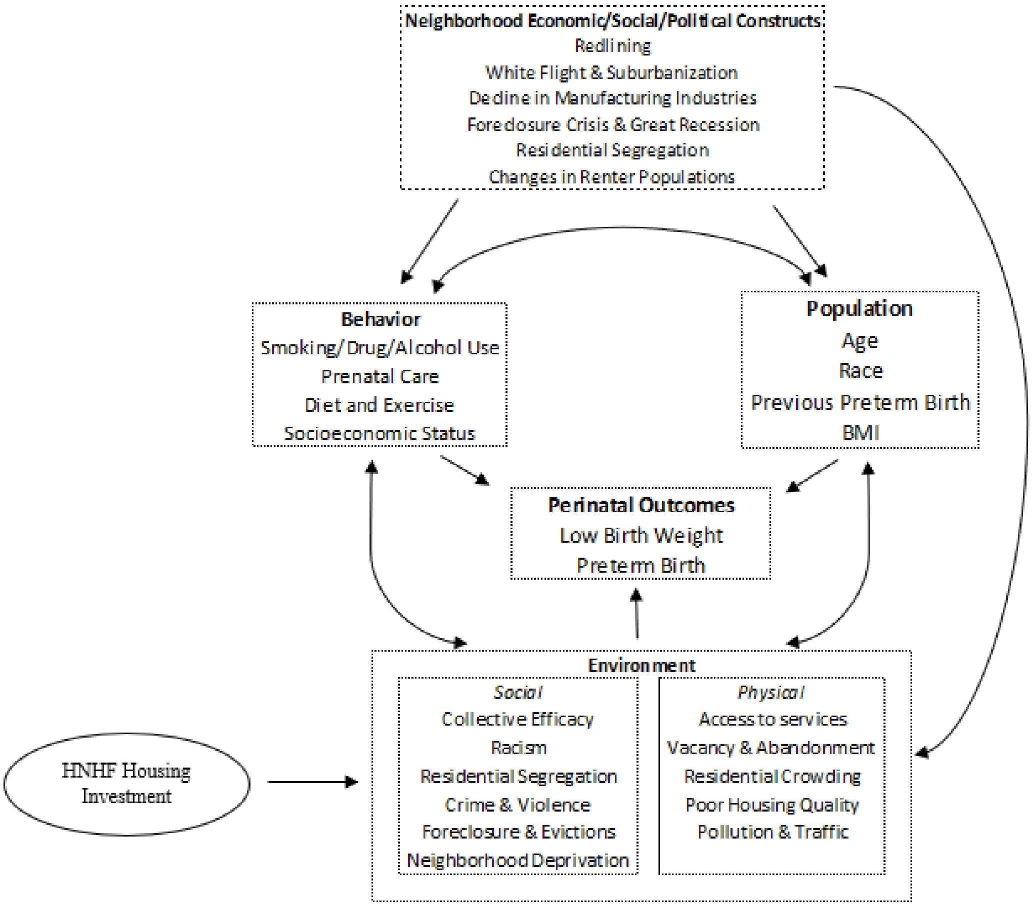

Figure 2. Theorized effects of the HNHF Housing investment on the neighborhood political ecology of Southside, Columbus

Population factors that influence adverse birth outcomes are individual factors, such as the age of a mother or their race. Mothers who utilize prenatal care are less likely to have a negative outcome delivery. Pre-existing health conditions can also impact birth outcomes. Women who have previously given birth preterm or have hypertension are more likely to deliver PTB or LBW.

Behavioral factors of mothers, which are influenced by social norms, economic limitations, and individual choice also affect birth outcomes. Mothers who partake in drug or alcohol use, as well as smoking, are at a higher risk for these negative outcomes. Economic constraints on socioeconomic factors can also increase risk. For example, women who are unemployed or earn low incomes may have limited funds for health-promoting resources such as healthy food. They may also have less access or options concerning health insurance or quality care. Finally, the stress from finances could increase risk for an early delivery and could potentially reinforce other risky behaviors, such as smoking or poor diet.

Environmental context, which consists of both social and physical components, is also important in reducing risk of PTB and LBW. Physically, healthy neighborhoods provide access to important health and social services, which is especially advantageous if mothers face more barriers due to lower socioeconomic status. Through stress inducing pathways, physical quality of a neighborhood can have detrimental effects on a mother's health. Vacancy, poor housing, overcrowding, and increased pollution and traffic all have proven associations with increased negative birth outcomes. Socially, decreasing physical qualities of a neighborhood can increase violence and crime. Neighborhoods that have high deprivation and are residentially isolated or segregated also have proven associations with adverse birth outcomes. Housing stability is also an important component in reducing risk of PTB or LBW. Many of these factors are conceptualized as stressful exposures for mothers. The Southside has been identified as a high-risk neighborhood for PTB and LBW in Columbus (City of Columbus City Council, 2014).

In the conceptual framework, all three components are influenced by "ultimate-tier" risk factors, or the social, economic, and political constructs of the neighborhood. In the context of the Southside, these constructs help explain how the conditions in the neighborhood, specifically related to the housing structure, have deteriorated over past decades. Following the Great Depression, the federal government's labeling of loans as risky in communities of color segregated Black residents in urban neighborhoods through redlining. These housing policies also favored new construction, which attracted wealthier urban residents to the open spaces of the suburbs. These events emptied the central cities and produced a decline in urban industry, specifically manufacturing jobs, which resulted in a high unemployment rate for urban populations. In the Southside, the loss of Crane Plastics and Columbus Castings was a severe economic setback to the area. The civil rights movement and passage of acts such as the Fair Housing Act of 1968 were targeted towards reducing inequalities in the United States. Instead, these events only fueled the already occurring migration of White residents and wealthier Black residents to the suburbs, further segregating communities and leaving behind residents essentially "stuck in place" (Sharkey, 2013). The systematic concentration of poverty and residential segregation has constructed distressed urban neighborhoods, such as the Southside. The resulting disinvestment, characteristic of many central city neighborhoods, has produced residential abandonment and a deteriorating older housing stock (Zuberi et al., 2016).

Exasperating Southside disinvestment are the more recent predatory lending practices that resulted in the Foreclosure Crisis and subsequent Great Recession. Subprime loans, with higher and sometimes variable rates, were meant as a bridge for more marginal applicants to access homeownership, the cultural and social symbol of success in America. However, a majority of minority borrowers who actually qualified for prime conventional loans were steered towards and utilized these high-cost high-risk mortgages (Barwick, 2009). African-American borrowers with credit scores of 660 or higher were 3.5 times more likely to receive subprime loans than White borrowers with the same credit scores (Bocia, Lei, Reid, & Quercia, 2011).

These types of loans were at the highest risk for delinquency. When the resulting recession hit, foreclosure followed, which resulted in a substantial loss of equity for many homeowners. The Southside was one of the hardest hit neighborhoods in Columbus from these events, which only increased the abandonment and related issues in the neighborhood.

Housing policy and social changes have also affected the Southside. Over the past few decades federal spending has decreased for project-based housing and has instead relied heavily on voucher programs. Residents who qualify for vouchers face difficulties in securing safe and affordable units, due to tight market conditions, shortages of moderately priced rentals, racial and ethnic discrimination, or landlords unwilling to accept payments (Turner, 2003). The movement back to cities, along with an increase in renter population has only increased competition for these more affordable units.

The final influence in the conceptual framework is the investment into the Southside's housing stock by HNHF. This work specifically addresses the physical environment component through improvement in housing quality and reduction in vacancy. Due to the interconnectedness of the framework, their work also conceptually influences the other two components. For example, an increase in neighborhood revitalization through housing could reduce crime and violence, which could subsequently reduce stress coping behaviors such as smoking. Investment in the neighborhood could also attract new businesses and services, which could provide mothers with healthy food and improved care. Due to the interconnectedness of the framework, each of these components in the framework are integral for incorporation into the analysis.

Methodological Approach.

Propensity Score Modeling.

Effective evaluation of the HNHF housing investment on adverse birth outcomes, requires selection of an appropriate comparison neighborhood. This analysis used propensity score modeling methods (PSM) to reduce the influence of confounding when using observational data. I use propensity scores to estimate the probability that a census tract which has not received the intervention is similar at baseline to a treated census tract (Rosenbaum & Rubin, 1983). These scores effectively balance the sample such that the distribution of identified key variables are similar for both treated and comparison areas. Selection of key variables were identified from the literature review guided by the conceptual framework and included these measures at baseline (Austin, 2011). Specifically, this analysis incorporated local-level measures of a neighborhood (Table 1). An innovative and central component of the analysis was the inclusion of tax parcel and assessor data in examining the role of the environment on birth outcomes. This readily available dataset provided information on the value, location, and physical characteristics of residential parcels. The outcome in PSM used logistic regression to regress treatment status on observed baseline factors (Austin, 2011). Exact matches on a balancing score are nearly impossible, however, the method formed matched sets of treated and untreated areas that shared a similar score. Selecting a statistically comparable neighborhood allowed for meaningful conclusions regarding the causal relationship between birth outcomes and housing.

Category	Variable	Date	Source
HNHF	HNHF Parcels	Present	HNHF
Parcel Data	% Residential Properties < Avg. Condition	2008	Franklin County Auditor
	Residential Avg. Median Sale Price (per SQFT)	2006-2009	Franklin County Auditor
Housing Instability	Foreclosure Rate	1/1/2007-6/30/2008	HUD
	Eviction Rate	2007	Eviction Lab
	% Vacant Properties (Residential, Business, Other)	2007 -2009	USPS/HUD
Neighborhood Housing	% Renter Occupied	2006-2010	American Community Survey
	Median Year Built	2006-2010	American Community Survey
	Median Home Value	2006-2010	American Community Survey
Demographics	Neighborhood Deprivation Index (NDI)	2006-2010	American Community Survey
	Population Density	2006-2010	American Community Survey
	% Black	2006-2010	American Community Survey
Crime	Total Crime Rate	2008	Columbus Police Department
	Violent Crime Rate	2008	Columbus Police Department
	Property Crime Rate	2008	Columbus Police Department
Segregation	Mortgage Lending Racial Bias Index	2007-2013	Home Mortgage Disclosure Act (Beyer et al. 2016)
	% Tract Redlined	1936	Home Owners Loan Corporation
Pollution/Air Quality	Traffic Related Air Pollution Index (TRAP)	2018	Ohio Department of Transportation

Table 1. Neighborhood-level measures included in PSM, dates, and sources.

To evaluate whether the propensity score was correctly specified, systematic differences in baseline covariates between treated and untreated areas were examined (Austin, 2011). As a robustness check, alternative definitions of the HNHF neighborhood were also utilized. PSM was run using multiple neighborhood construction methods, by aggregating different combinations of census tracts based on type of investment in the tract (majority rental vs. homeowner).

Difference in Differences Modeling.

Once appropriate comparison neighborhoods were selected, the second part of the analysis consisted of difference-in-differences regression modeling (DID) in order to estimate the effect of the investment on birth outcomes identified from Ohio Department of Health vital birth records data. DID models assume a parallel trend over time between neighborhoods and therefore controls for both measured and unmeasured factors affecting the outcomes. Due to the similarity of the neighborhood contexts identified during PSM, the differences between the two areas should remain constant over time absent an intervention. Any difference in changes between the two areas can be attributed to the intervention.

Generalized Linear Regression models were used to estimate DID coefficients, along with critical covariates, with each respective birth outcome as the binary dependent variable. The following model was run for each outcome:

DID Model:

$$y = \beta_0 + \beta_1 Post + \beta_2 HNHF + \beta_3 (Post \times HNHF) + \varepsilon$$

y was the binary dependent variable indicating whether a PTB or LBW occurred. β_0 specified the baseline average for each respective outcome. *Post* was the time variable indicating whether the birth occurred in the pre-period (0) or post-period (1) of the study and represented the time trend in the comparison neighborhood(s). *HNHF* indicated whether the birth occurred in HNHF (1) or comparison neighborhood(s) (0). The coefficient for *HNHF* examined the differences in PTB or LBW probability between the two groups before the intervention. Finally, the DID estimate was the interaction term between *Post* and *HNHF,* which estimated how the odds of a birth outcome changed for those in the Southside neighborhood during the HNHF intervention relative to those who lived in the comparison(s). A negative and significant interaction term indicated that the intervention had a positive effect, decreasing the odds of either PTB or LBW in the Southside relative to the comparison(s) during the intervention time period.

CHAPTER 2: ANALYSIS OF A NEIGHBORHOOD HOUSING INTERVENTION AND BIRTH OUTCOMES

Abstract

Racial and geographic disparities in adverse birth outcomes are a national public health crisis. Investment in individual maternal programs has had insignificant effects on reducing preterm birth and low birthweight rates. Focus has turned to a mother's environmental context and intervention on certain factors, such as housing. Using local-level variables relating to historical and current neighborhood context, we develop a methodology to select a comparison neighborhood for evaluation of such neighborhood health interventions. We then examine differences in adverse birth outcomes after a housing intervention in the Southside neighborhood of Columbus, Ohio. This new comparison selection methodology can be used to evaluate changes in other health outcomes with hypothesized relationships to housing.

Introduction

In recent decades a renewed interest in the synergistic relationship between people and place has resulted in the expansion of theoretical frameworks and methodological advancements in neighborhood effects research (Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Kawachi and Berkman, 2003; Macintyre & Ellaway, 2003). Driven by a recognition of the limitations in individual-based explanations of disease, the interest in neighborhoods specifically as a context has emerged (Roux & Mair, 2010).

A prime example of the importance of incorporating neighborhood context into analysis are adverse birth outcomes. Preterm birth (PTB) and low birthweight (LBW) are serious public health issues. In developed countries healthcare and technology advances have insignificantly reduced the rising rates for these outcomes. Individual risk factors for PTB an LBW include demographic characteristics, including age and race, as well as socioeconomic characteristics, such as income or education, or behavioral characteristics, such as smoking or prenatal care. Although women of a lower socioeconomic status face a greater risk for an adverse birth outcome, this characteristic has failed to account for the racial disparities that exist (Lieberman, Monson & Schoenbaum, 1987; Kleinman & Kessel, 1987). Black women are two-times more likely than White women to have an adverse birth outcome and this disparity has persisted for decades (Behrman, 1987; Blackmore, Ferre, Rowley, Hogue, Gaiter, & Atrash, 1993).

Disparities also exist in the geographic distribution of PTB and LBW. In Franklin County, Ohio, PTB and LBW rates are concentrated in areas that have higher rates of neighborhood disadvantage, including higher percentages of population living in poverty, high housing cost burdened, higher vacancy rates, and predominantly Black populations (Reece & Norris, 2014). An explanation for the persistent racial and spatial disparities is the striking differences in the neighborhoods where Black and White mothers typically reside (Metcalfe et al., 2011; Ncube et al., 2016). Black mothers are significantly more likely to live in an impoverished census tract relative to White mothers (Collins & David, 1990). Neighborhood context is therefore a vital component to understanding birth outcomes, as individual factors alone fail to explain associations between maternal characteristics and birth outcomes.

The housing structure of a neighborhood has emerged as a contextual variable of interest, as it plays a multitude of roles in defining a neighborhood. Housing provides safety and shelter, influences resident well-being, and facilitates important social interactions. Housing also serves as a source of identity and pride for residents. Additionally, high quality housing is characteristic of healthy neighborhoods, which provide residents with advantageous benefits, such as support from neighbors, top performing schools, healthy food environments, safe places to play and exercise, as well as access to economic opportunities, quality transportation, and important social services. However, access to healthy neighborhoods and homes is not always equitable and obstacles can introduce deleterious effects on health. As the foundation of both the social and physical fabric of neighborhoods, there are four major pathways through which housing reduces health: physical quality, location, stability, and affordability.

Populations living in inadequate or substandard housing are at higher risk for a host of health issues (Jacobs, 2011). Proven associations between poor housing quality and health include respiratory issues, infectious diseases, chronic conditions, lead poisoning, injuries, and poor mental health (Krieger and Higgins, 2002). Poor housing conditions often coexist, placing residents at risk for multiple health problems (Braverman et al., 2008). Neighborhood decay from poor quality housing can further affect mental health of residents. Resident perceptions of abandonment include loss of control over neighborhood life, fractured neighbor ties, concern for crime and safety, increased anxiety and depression, and negative financial strains (Garvin et al., 2013).

Residential mobility can also create neighborhoods of disadvantage, when those who lack the resources to move are isolated. Disinvestment in neighborhoods reduces the quality of the housing stock, creating a ripple effect of disinvestment in schools, jobs and services. Further, racial segregation has produced socially and geographically isolated communities, which are strongly correlated with neighborhood disadvantage (Sampson et al., 2002). The source of many health disparities in racially segregated neighborhoods is not residential segregation itself, but the subsequent increase of concentrated poverty, increasing disparities in access to schools, jobs and healthcare.

While the ability to move can potentially improve the health of residents, those who experience forced moves are at a greater risk for health issues. Residential instability encompasses many challenges, such as moving frequently, falling behind in mortgages or rent, and overcrowding (Kushel et al., 2006). As a chronic stressor, individuals that experience residential instability are at a greater risk for anxiety and depression (Burgard et al., 2012). Further escalating these effects, instability can carry over into other aspects of life, disrupting employment, social networks, education and receipt of social service benefits (Desmond, 2016). Residential instability is largely associated with the rising cost of housing and decreasing supply of affordable homes and rental units.

A growing percentage of Americans are facing difficulties securing safe and affordable housing. In 2011, one-third of all homeowners and half of renters spent more than 30% of their income (the affordable rate) on housing (Schwartz, 2015). Cost burdens produce multiple stressors for households. When a greater percentage of income is devoted to housing, other needs, such as healthcare or nutritious food, are sacrificed. Moreover, financially strained residents are also more likely to postpone needed treatment or care (Harkness & Newman, 2005). Foreclosures, a product of financial strain, are not only significant financial stressors for residents, but also the surrounding neighborhood. Homeownership is a major source of equity for most Americans. Surrounding property values decline during foreclosure, resulting in a loss of equity for both homeowner and neighbors (Immergluck & Smith, 2006). In a 2016 study, residence in a high-rate foreclosure neighborhood resulted in an increased utilization of hospitals and emergency rooms for a variety of conditions, including mental health conditions, heart attack, stroke, and hypertension (Currie & Tekin, 2016).

To understand the inequality in neighborhood housing quality, location, stability, and affordability, it's important to also consider the social, political, and economic constructs of a neighborhood. Specific current and historical events have led to the abandonment and racial inequality of certain neighborhood environments. Historical housing policies favoring new construction and discrimination against Black applicants using redlining encouraged residential flight and the rise of suburbanization for predominantly wealthy White residents (Wilson, 2012). Disinvestment in central cities resulted not only in a large loss of tax money, but also a decline in manufacturing jobs and other urban industry which further fueled the decline of neighborhoods in many U.S. metropolitan areas. The systematic concentration of poverty and residential segregation produced distressed urban neighborhoods (Starkey, 2013). More recently, predatory lending practices resulting in the Foreclosure Crisis disproportionately targeted high-cost loans at minorities who faced the highest risk for delinquency (Barwick, 2009). Foreclosures further intensified abandonment in these already declining neighborhoods. Lastly, federal spending on housing shifted from project-based assistance to vouchers in the private market (Schwartz, 2015). Although these programs allow residents freedom and mobility, the demand for safe and affordable housing surged. An increase in renters and movement back to the cities has created intense competition for these units (Joint Center for Housing Studies, 2017). These combined processes led to the decline in physical housing quality and an increase in neighborhood disadvantage.

Focused interventions on an individual's context have the potential to indirectly affect health outcomes (Roux & Mair, 2010). Complex feedback loops and mechanisms by which an individual's residential environment affects their health have made intervening on specific contextual factors difficult in past research (Macintyre & Ellaway, 2003; Roux & Mair, 2010).

Further complicating neighborhood effects literature are methodological limitations. A systematic review by Arcaya et al. in 2016 showed over 70% of neighborhood health effects studies were cross-sectional (Arcaya, Tucker-Seeley, Kim, Schnake-Mahl, So, & Subramanian, 2016). Cross-sectional studies are beneficial in examining associations and generating preliminary evidence but are relatively weak in establishing causal inference. Experimental studies considered the "gold standard" in research have the potential to fill a gap in neighborhood effects research and further illuminate opportunities for area-level exposures to improve health (Schmidt, Nguyen & Osypuk, 2018).

Housing interventions are limited. Most involve relocating whole communities to higher opportunity areas, which is rarely desirable nor feasible (Acevedo-Garcia, Osypuk, Werbel, Meara, Cutler, & Berkman, 2004; Orr et al., 2003; Rubinowitz & Rosenbaum, 2000). A novel intervention which addresses housing at a neighborhood-level is the Healthy Neighborhoods Healthy Families (HNHF) initiative from Nationwide Children's Hospital. Situated in a distressed neighborhood on Columbus's Southside, the hospital witnessed first-hand the relationship between health and place. At the beginning of the study period over half of the children in the area were living below the poverty line (ACS, 2010). As an accountable care and mission-driven organization, the hospital began treating the neighborhood as a "patient." The most prevalent symptom of the Southside was a lack of quality housing and residential stability (Kelleher et al., 2018). Vacancy in the area was almost three-times greater than the Columbus Metropolitan Statistical Area, 56% of mortgages were considered high-cost loans, and foreclosures were double the rate for Franklin County (HUD, 2007). The neighborhood was identified as a "hotspot" for infant mortality in the city (City of Columbus City Council, 2014). In an effort to stabilize homeownership, HNHF began investing in the housing stock of the neighborhood. Over the past decade, through acquisition and renovation of vacant properties, subsidization of owner-occupied repairs, and expansion of access to affordable rentals, the organization has impacted over 300 residential properties (Kelleher et al., 2018). Although the work was done on individual parcels, HNHF hypothesized that benefits from single parcel investments would "spillover" to the surrounding environment, as physical features impact social processes and behaviors of a neighborhood as a whole. Their revitalization of the neighborhood has attracted outside investment to the area, yet the affordable model safeguards current residents from displacement.

The HNHF investment provides a unique quasi-experimental study design for evaluation of many health outcomes, rare in neighborhood health effects research. In this paper, we focus specifically on two negative birth outcomes: preterm birth (PTB) and low birthweight (LBW). Although popular in applied research, quasi-experimental studies are a largely absent and underutilized tool for testing neighborhood effects in health research (Oakes, Andrade, Biyoow, & Cowan, 2015). Historically, neighborhood health effects research has overlooked generalizability of results, yet non-random assignment of exposure in quasi-experimental studies is more likely to mimic real world settings, making subsequent results more applicable to other areas and populations (Osypuk et al., 2015; Schmidt et al., 2018).

Non-randomized exposure in quasi-experimental studies has the potential to increase threats to internal validity. Evaluation of the HNHF investment therefore requires the use of a strong conceptual framework for comparison neighborhood selection, in order to reduce confounding and increase causal inference. This analysis will use a novel approach combining neighborhood-level measures beyond census variables for control selection. A unique component of the analysis will be the incorporation of digitized tax parcel data from the county auditor's office, which contains condition and assessment data for each parcel in Franklin County. To our knowledge, there have been no quasi-experimental studies that have tested the effect of a neighborhood housing investment on birth outcomes. We fill this gap in the literature using a novel method for comparison selection, as well as difference-in-differences (DID) modeling.

Methods

Treatment Area

The HNHF treatment areas is defined as ten contiguous census tracts in Columbus's Southside. Majority of investment is concentrated in census tracts 56.10 and 56.20, although all have seen some type of investment. Further, certain tracts have a greater magnitude of specific investment strategy (rental vs. homeownership). The pre-treatment time period is defined as 2007-2008, while the post time period is 2015-2016.

Measures of Neighborhood Context

Census tract-level neighborhood measures were collected for the pre-period and used in propensity score modeling to identify candidate comparison communities. Using a geographic information system (GIS) in ArcGIS version 10.3.1, constructed data layers were overlaid to integrate and analyze these measures (Figure 3) (ESRI, 2014). Due to the abandonment the Southside has experienced throughout history, measures of interest were specifically related to neighborhood housing structure, racial segregation and socioeconomic conditions.

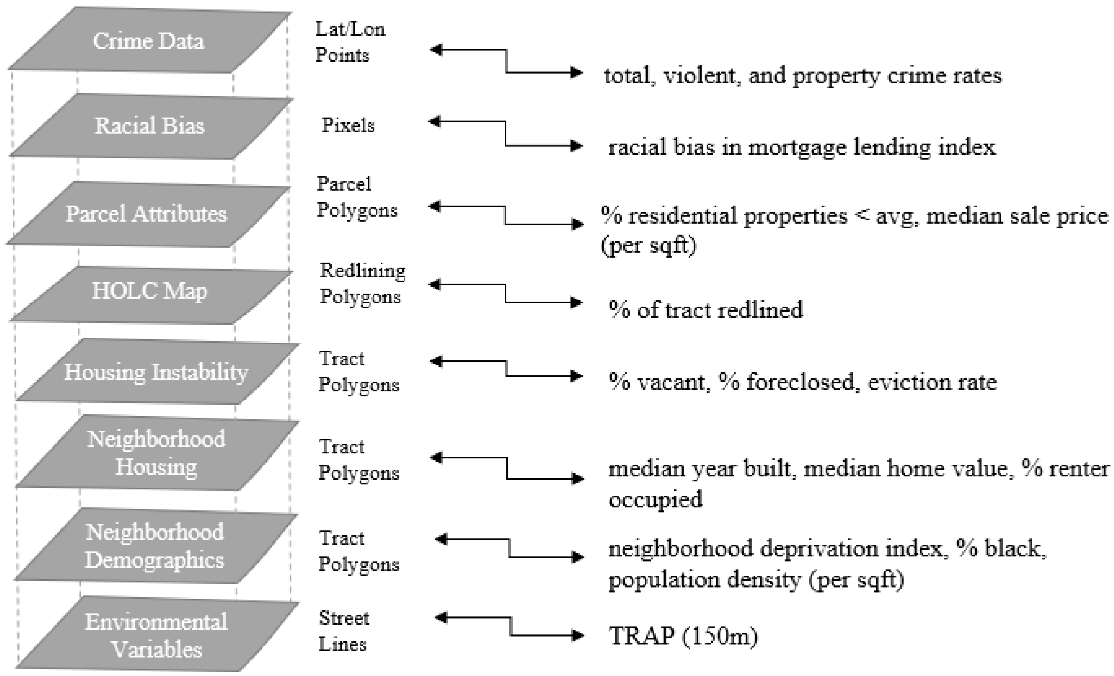

Figure 3. Data layers and type included in propensity score matching analysis

Demographics

Neighborhood demographic values from the 2006-2010 ACS included **population density (per sq. mile)** and **% Black.**

Neighborhood Deprivation Index

A **neighborhood deprivation index** was developed for each census tract in Franklin County based on methodology by Messer et al. in previous birth outcomes research (Messer et al., 2006). This index incorporates the following variables at the census tract level: % less than a high school degree (25 years and older), % in or below the poverty level, % of female households with children under 18, % with public assistance or food stamps, % unemployed (16-64 years old in labor force), and % with less than 30k annual household income. Using the combined data from the ACS five-year estimates (2006-2010), Principal Component Analysis was performed using these variables to create a standardized index of socioeconomic deprivation. Higher index scores correlate to higher neighborhood deprivation.

Crime

Census tract **total, violent, and property crime rates** were calculated using Columbus Police Department reports for 2008. Along with total crime, subsets of crime counts for property and violent crime were computed. Reports containing universal crime reporting (UCR) descriptions of burglary, larceny-theft, motor vehicle theft, and arson, were categorized as property crimes. Murder, non-negligent manslaughter, forcible rape, robbery and aggravated assault were further categorized as violent crimes. Census tracts were assigned to crime incidents based on coordinates of the reports and counts were aggregated to the census tract level. These counts were normalized using total population values from the 2006-2010 ACS.

Residential Instability

Aggregated vacancy data was provided quarterly by the United States Postal Service (USPS) and the U.S. Department of Housing and Urban Development (HUD) for Franklin County census tracts between 2007-2009. **Percentage of vacant properties** was calculated for each tract using the total number of USPS addresses and whether addresses were vacant for 90 days or longer. HUD also published a dataset containing **foreclosure rates** estimated for each census tract for 2007 and the first half of 2008.

Eviction rates were obtained through The Eviction Lab at Princeton University (Desmond et al., 2018). The lab used multiple methods to increase validity of eviction estimates, including requested bulk report of eviction cases directly from courts, web scraping and text parsing of online portals, as well as working with companies that manually collect records. The denominator of the rate is the number of occupied renting households in each census tract computed from the 2000 and 2010 U.S. Censuses and ESRI Business Analyst 2016.

Housing Characteristics

Housing variables were obtained from January 1, 2008 digitized tax parcel data from the Franklin County auditor's office, supplemented by ACS data. Parcel data is developed using real property inventory including record deeds, survey plats, unmanned aerial vehicle photos, and other public records, which are updated monthly. This geospatial data set contains many descriptive property attributes, including purchase price, condition, and assessed value. Census tract boundaries were overlaid to extract each parcel's geoid. Property conditions were ranked for each parcel (very good, good, average, fair, or poor). The frequency of below average residential properties was aggregated by census tract and divided by the total number of residential properties, to compute the **% of residential properties below average**. Census tract **median sale price per sq. foot** was also computed for residential, single family parcels sold for over $500 between 2006-2009. ACS 2006-2010 measures of **median home value, % renter occupied households,** and **median year built** were also included.

Segregation and Residential Discrimination

A **racial bias in mortgage lending index** was developed and provided to our team by Beyer et al., 2016. Their index uses conventional loan outcomes from the 2007-2013 Home Mortgage Disclosure Act to estimate a continuous surface of mortgage lending racial bias. Using adaptive spatial filtering, a grid was placed over the study area. From each grid point the nearest geographic units were aggregated by expanding the radius of the filter until two White loan approvals and denials, as well as two Black loan approval and denials were obtained. For each filter, the odds of a Black applicant being denied relative to a White applicant were computed using logistic regression, controlling for sex and ratio of loan amount to applicant's income. The index was ultimately summarized using mean pixel values by census tract.

To combine historical practices of racial discrimination into the neighborhood context, the 1936 Home Owner's Loan Corporation residential security map for Columbus was overlaid by census tract boundaries. The resulting **percentage of census tracts overlapping with redlined areas** was computed.

Pollution & Air Quality

Due to the limited number of air quality monitoring stations in Franklin County and spatial variation in urban air pollutants from traffic, a **traffic-related air pollution (TRAP) metric** was calculated for each census tract. As concentrations of traffic-related air pollutants decline within approximately 150m of a road, this distance was used to create buffers around each census tract (Knape, 1999). The final metric contained the summation of all major road lengths within buffers.

Selection of Comparison Neighborhoods

Since random assignment is not possible in quasi-experimental studies, methods should ensure comparison areas were not significantly different than those in the treatment area at baseline by controlling for potentially unobserved confounders. Use of propensity score modeling (PSM) methods reduce the influence of confounding when using observational data. Although generally applied to individual-level data, this method identifies census tracts in Franklin County that are similar at baseline to the HNHF area before treatment. Using R software package 'MatchIt' and nearest neighbor matching, logistic regression models estimated the probability of a census tract being assigned to the treatment for all Franklin County tracts (Ho et al., 2011). This method also balanced the distribution of the above neighborhood contextual variables.

PSM was run using multiple treatment neighborhood construction methods. Aggregation of tracts depended on the type of investment in each tract. For example, census tracts 56.10 and 56.20 contained mostly home repairs and home renovations, while census tract 61.00 contained a majority rental properties. Three potential treatment definitions could occur: one containing all treatment census tracts, regardless of investment type, another with majority rental tracts, and a final model containing majority homeowner tracts. Hotspots of PTB and LBW in the pre-study period are overlaid by these treatment definitions in Figure 4. Due to power limitations, not all variables were included in the homeowner and rental models, which had smaller numbers of treatment tracts. Based on the principle idea in neighborhood health research that similar populations group, high propensity census tracts were expected to cluster. Comparison neighborhoods were constructed by aggregating these high propensity census tracts. Evaluation of the neighborhoods selected using the propensity score models included jitter plot and standardized difference analysis.

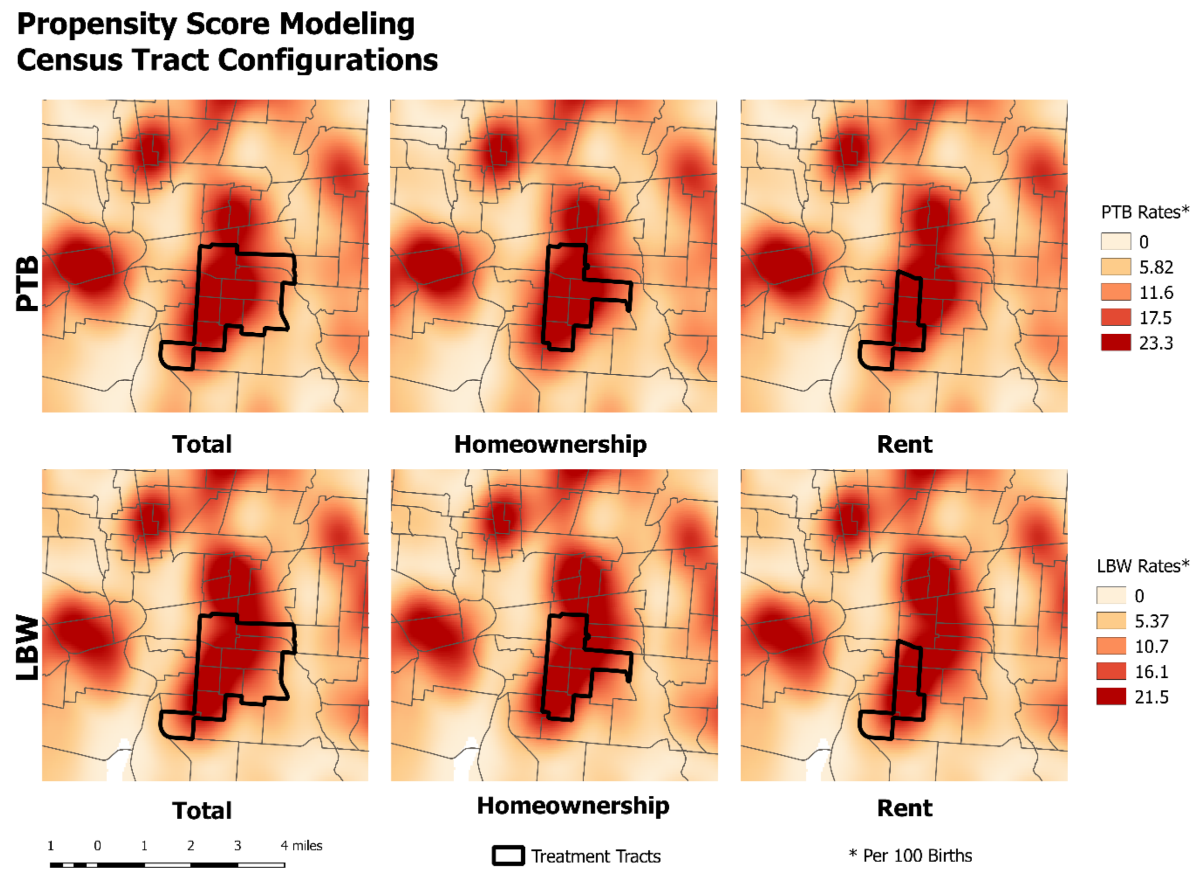

Figure 4. Propensity Score Modeling treatment census tract configurations and birth outcome hotspots

Birth Data

Birth outcome data was obtained from the Ohio Department of Health vital statistic birth records. This dataset contains important individual characteristics about infant, mother, and father, including address of residence at the time of birth. Previously cleaned and geocoded addresses were used to identify mother's census tract of residence. Only those that were successfully geocoded to a USPS street address were included in the final dataset (~99.1%). The study population was further restricted to singleton births from mothers aged 14 to 44. Mothers had to have given birth between 21 and 45 weeks of obstetrician calculated gestation and to infants greater than 500g but less than 5500g of birth weight. Births outside of these criteria likely represent data entry errors or extreme outliers. Only mothers with available information on prenatal care were included as this was an important covariate in our analysis. All other covariates with missing observations were coded as missing dummy variables. Finally, mothers had to reside in a census tract of interest during the pre and post time periods and have complete gestation and birth weight data (**n = 5,082**).

Low birthweight was defined as infants weighing less than 2500g at birth. Premature births were those delivered before 37 weeks of obstetrician calculated gestation. Potential maternal covariates included race, education, age, marital status, smoking status, body mass index (BMI), prenatal care, previous preterm delivery, hypertension, Medicaid enrollment, and number of previous births.

Difference in Differences Modeling

To evaluate the variation in birth outcomes between treatment and comparison neighborhoods, exploratory analysis examining associations between potential covariates and the outcomes of interest was first conducted using descriptive statistics and logistic regression models. Once the most parsimonious model was produced, difference-in-differences (DID) modeling was used to estimate relative change in each outcome between the pre and post periods. Due to the similarity in neighborhood contexts identified during PSM, the differences between the two areas should remain constant over time, absent an investment.

Generalized Linear Regression models were used to estimate DID coefficients, along with critical covariates, with each respective birth outcome as the binary dependent variable. The following model was run for each outcome:

DID Model:

$$y = \beta_0 + \beta_1 Post + \beta_2 HNHF + \beta_3 (Post \times HNHF) + \varepsilon$$

This model was used to estimate the DID for HNHF relative to identified comparison areas pooled together, as well as each separately. *y* was the binary dependent variable indicating whether a PTB or LBW occurred. β_0 specified the baseline average for each respective outcome. *Post* was the time variable indicating whether the birth occurred in the pre-period (0) or post-period (1) of the study and represented the time trend in the comparison neighborhood(s). *HNHF* indicated whether the birth occurred in HNHF (1) or comparison neighborhood(s) (0). The coefficient for *HNHF* examined the differences in PTB or LBW probability between the two groups before the intervention. Finally, the DID estimate was the interaction term between *Post* and *HNHF,* which estimated how the odds of a birth outcome changed for those in the Southside neighborhood during the HNHF intervention relative to those who lived in the comparison(s). A negative and significant interaction term indicated that the intervention had a positive effect, decreasing the odds of either PTB or LBW in Southside relative to the comparison(s) during the intervention time period.

All models controlled for maternal covariates which were significant in the exploratory analysis. Incorporating these variables controls for individual demographic changes that may occur during the study period. The DID estimate is therefore the direct effect from the intervention. After modeling, predictive margins were calculated for each model to estimate the magnitude of effect. Hosmer-Lemeshow tests and Variance inflation factors (VIFS) indicated the model was correctly specified, and that multicollinearity was not an issue.

As a sensitivity analysis, we used the same model as above to conduct DID analysis using different geographic aggregations of census tracts based on propensity score output (Appendix A). We compared DID estimates at each geographic level to determine sensitivity of results due to changes in neighborhood definition. R (R Core Team, 2018) was used to conduct all analyses.

Results

Figure 5 displays the PSM results using the three treatment construction methods (outlined in red). Jitter plot analysis for each scenario showed that distributions of matched comparison tracts were much closer to the matched treated than unmatched comparison tracts. PSM minimized the difference in means between each factor, apart from the redlining in the total and homeowner model, racial bias index variables in the total model, and percent Black in the rental model (Table 2). However, the inclusion of these variables decreased overall standardized differences in each model and were ultimately included. Finally, F-tests indicated there were minimal significant differences between the means of each variable after matching. These results together indicate PSM reduced differences between the treatment and comparison tracts.

	Total PSM		**Homeowner PSM**		**Rental PSM**	
	All	Matched	All	Matched	All	Matched
Distance	2.21	1.35	1.63	0.38	1.88	1.11
< Avg. Condition	2.54	0.02	3.63	-0.31	3.80	0.89
Sale Price	-7.77	-0.61				
%Foreclosure	8.48	2.04	8.87	0.18		
Eviction Rate	3.55	0.61	3.63	0.78	3.34	-1.78
% Vacant	2.03	0.17	2.08	0.03	1.71	-0.07
% Rent	0.80	-0.01	1.53	-1.08	2.11	0.45
Median Year Built	-3.79	-0.78				
Median Home Value	-6.65	0.63	-6.77	0.42	-6.97	0.63
NDI	2.26	-0.10	4.74	-1.31	2.81	0.22
Pop. Density	0.98	0.33	1.75	-0.01	1.79	0.74
% Black	1.27	0.23	1.40	0.21	0.27	-0.71
Violent Crime Rate	1.48	0.18				
Property Crime Rate	2.01	0.32				
Total Crime Rate	1.90	0.20	2.34	-0.90	3.10	-0.05
Racial Bias Index	-0.03	0.23				
% Redlined	0.52	-0.73	0.20	-0.86	0.51	0.38
TRAP	-0.65	0.30				

Table 2. PSM model standardized differences overall and by variable for all and matched census tracts

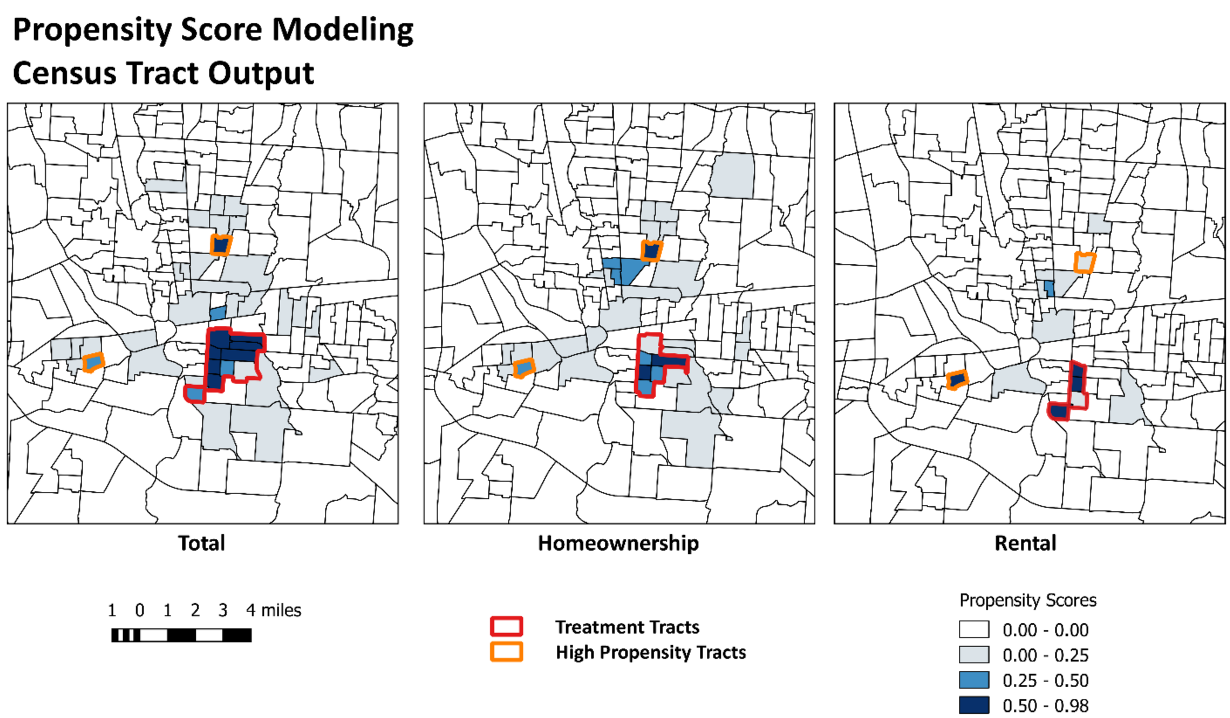

Figure 5. Propensity scores by treatment configuration from modeling output

PSM results were similar across the three scenarios, warranting the same comparison areas regardless of investment type. Two census tracts, census tract 7.30 and 48.20, continually had the highest likelihood. Following our clustering hypothesis, higher probabilities occurred in neighboring census tracts to these two. These tracts were aggregated around 7.30 and 48.20 to create two comparison areas (Figure 6). We tried to be cognizant of natural boundaries such as the Scioto River or highways that would separate areas, as well as local knowledge of Columbus's distinct neighborhoods. All three of these areas contained tracts identified as high-risk for infant mortality by a city task force (City of Columbus City Council, 2014). Table 3 provides the mean values for each variable in the aggregated HNHF and Comparison area tracts, as well as Franklin County. The mean values in these neighborhoods are much closer to HNHF, relative to the rest of Franklin County.

Analysis of variance results in Table 3 also indicated there were only significant differences between mean values for % Black and % Vacant Buildings. Post Hoc Analysis using the Tukey Test indicated the significant difference for % Black was between HNHF and Comparison 2. Comparison 2 (27.0%) had a much lower Black population relative to HNHF (64.1%). The significant difference between % vacant buildings occurred between Comparison 1 and Comparison 2. Comparison 1 (15.7%) had a much higher percentage of vacant buildings relative to Comparison 2 (8.8%). Even though these differences were significant, values were still closer between these neighborhoods than Franklin County as a whole. We were also less concerned with the significant difference between our two comparison areas, since comparison of these areas was not vital to answer our research questions.

On average, the treatment and comparison areas had higher neighborhood deprivation, and residents faced more evictions and foreclosures, relative to Franklin County. The average properties were also older and in worse condition, sold for less, and were less valuable. These areas historically faced greater racial discrimination due to redlining and had higher vacancy and crime rates. Surprisingly, Franklin County had a higher TRAP score than our areas of interest, which may be due to the extensive interstate and highway system that occurred in certain tracts in Columbus, such as downtown, creating outliers which skewed the overall average.

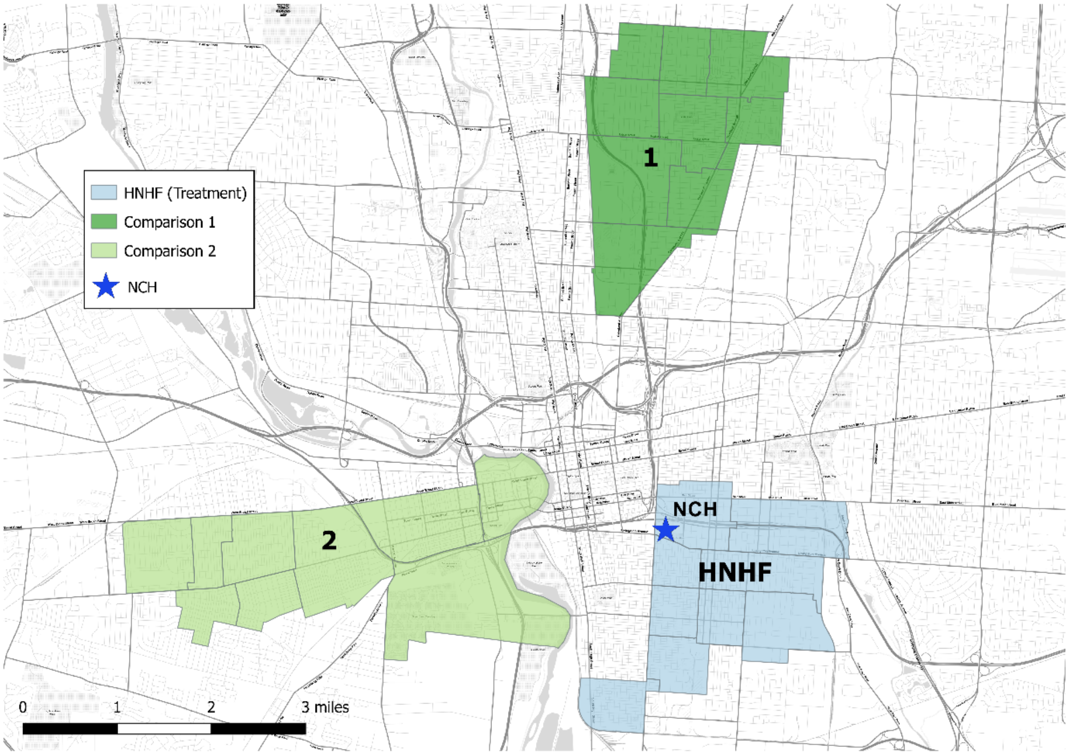

Figure 6. HNHF and comparison areas in Columbus identified using propensity score modeling

	Modeling Variables	HNHF	Comparison 1	Comparison 2	F-Test	Franklin County
Demographics	NDI	1.43	1.26	1.55	0.26	-0.07
	Population Density (per sq. mile)	6,463	5,568	6,479	0.41	4,384
	%Black	64.1%	57.2%	27.0%	5.08*	23.4%
Crime	Total Crime Rate (per 100 population)	23.50	19.00	23.10	0.68	8.10
	Property Crime Rate (per 100 population)	6.40	5.40	6.90	0.90	2.60
	Violent Crime Rate (per 100 population)	2.00	1.60	1.90	0.27	0.50
Housing	Median Sale Price per SQFT (06-09)	$38.10	$47.83	$42.19	0.93	$93.12
	% Condition Below Average (Res Props)	19.3%	14.8%	16.3%	0.49	5.3%
	% Rent	54.9%	50.6%	55.2%	0.23	43.7%
	Median Year Built	1943	1948	1947	1.27	1968
	Median Home Value	$80,110	$70,433	$70,933	0.74	$158,220
Housing Instability	% Mortgages Foreclosed	13.2%	13.6%	11.7%	0.71	6.9%
	% Vacant Buildings	13.8%	15.7%	8.8%	4.85*	4.3%
	Eviction Rate (per 100 renter homes)	10.69	10.65	9.96	0.23	5.48
Housing Discrimination	Mortgage Racial Bias Index	3.80	1.19	2.46	0.95	3.93
	% Redlined	12.1%	16.8%	17.1%	0.18	3.9%
Environmental	TRAP 150m	3,368	1,842	4,715	2.44	5,109

Table 3. Baseline mean values of neighborhood-level characteristics for HNHF, comparison areas, and Franklin County and Analysis of Variance results between HNHF, Comparison 1, and Comparison 2

$*$ = p value < 0.05

DID Results

Table 4 displays descriptive statistics for all births included in the study by time period and area. In each area, birth prevalence increased over the study period, however Comparison 1 experienced the largest increase (32%), while Comparison 2 increased only marginally (3%). Comparison 1 was also the only area to experience decreases in both PTB (26%) and LBW (21%). Distributions of covariates were similar for populations in all study areas. The average mother was between 25-34 years old, high school or less educated, did not smoke during pregnancy, was Medicaid enrolled, and had a healthy weight. The average age of the mother increased for all areas during the study period.

There were a few differences between areas and study periods. The most striking difference was the larger White population in Comparison 2 (59%-67%), relative to both HNHF (30%-31%) and Comparison 1 (34%-36%), which supported our findings from the PSM. There were also notable demographic changes for pregnant mothers in Comparison 1. The number of women who were neither Black nor White increased the most in Comparison 1 (4% to 10%). While each area experienced gains in education, in Comparison 1 there was a substantial decrease in the number of mothers with less than high school education (41% to 27%) supplemented by a large increase in those with education beyond high school (27% to 37%).

	HNHF		Comparison 1		Comparison 2	
	Pre = 738	Post = 827	Pre = 563	Post = 742	Pre = 1090	Post = 1122
N(%)						
Birth Outcomes						
PTB	88 (11.92)	113 (13.66)	69 (12.26)	69 (9.3)	125 (11.47)	130 (11.59)
LBW	89 (12.06)	109 (13.18)	67 (11.9)	69 (9.3)	104 (9.54)	130 (11.59)
Maternal Race						
White	223 (30.22)	259 (31.32)	203 (36.06)	254 (34.23)	726 (66.61)	664 (59.18)
Black	485 (65.72)	513 (62.03)	337 (59.86)	413 (55.66)	273 (25.05)	321 (28.61)
Other	30 (4.07)	55 (6.65)	23 (4.09)	75 (10.11)	91 (8.35)	137 (12.21)
Maternal Education						
More than HS	206 (27.91)	252 (30.47)	150 (26.64)	272 (36.66)	242 (22.2)	307 (27.36)
HS	218 (29.54)	287 (34.7)	168 (29.84)	256 (34.5)	304 (27.89)	365 (32.53)
Less than HS	296 (40.11)	269 (32.53)	229 (40.67)	198 (26.68)	523 (47.98)	427 (38.06)
Unknown	18 (2.44)	19 (2.3)	16 (2.84)	16 (2.16)	21 (1.93)	23 (2.05)
Age						
> 20	172 (23.31)	93 (11.25)	126 (22.38)	70 (9.43)	227 (20.83)	142 (12.66)
20-24	243 (32.93)	297 (35.91)	170 (30.2)	224 (30.19)	383 (35.14)	363 (32.35)
25-34	280 (37.94)	358 (43.29)	234 (41.56)	372 (50.13)	422 (38.72)	511 (45.54)
35-39	32 (4.34)	68 (8.22)	26 (4.62)	63 (8.49)	45 (4.13)	93 (8.29)
40+	11 (1.49)	11 (1.33)	7 (1.24)	13 (1.75)	13 (1.19)	13 (1.16)
Smoking Status						
No	478 (64.77)	559 (67.59)	380 (67.5)	531 (71.56)	624 (57.25)	716 (63.81)
Yes	233 (31.57)	245 (29.63)	153 (27.18)	200 (26.95)	448 (41.1)	391 (34.85)
Unknown	27 (3.66)	23 (2.78)	30 (5.33)	11 (1.48)	18 (1.65)	15 (1.34)
BMI						
Underweight	42 (5.69)	47 (5.68)	23 (4.09)	36 (4.85)	75 (6.88)	59 (5.26)
Healthy	283 (38.35)	317 (38.33)	209 (37.12)	246 (33.15)	449 (41.19)	442 (39.39)
Overweight	146 (19.78)	177 (21.4)	115 (20.43)	160 (21.56)	241 (22.11)	256 (22.82)
Obese	203 (27.51)	218 (26.36)	153 (27.18)	248 (33.42)	263 (24.13)	309 (27.54)
Unknown	64 (8.67)	68 (8.22)	63 (11.19)	52 (7.01)	62 (5.69)	56 (4.99)
Medicaid						
No	193 (26.15)	209 (25.27)	227 (40.32)	214 (28.84)	345 (31.65)	269 (23.98)
Yes	509 (68.97)	614 (74.24)	310 (55.06)	527 (71.02)	725 (66.51)	851 (75.85)
Unknown	36 (4.88)	4 (0.48)	26 (4.62)	1 (0.13)	20 (1.83)	2 (0.18)
Previous Preterm						
No	701 (94.99)	705 (85.25)	537 (95.38)	652 (87.87)	1050 (96.33)	981 (87.43)
Yes	30 (4.07)	122 (14.75)	25 (4.44)	90 (12.13)	33 (3.03)	141 (12.57)
Unknown	7 (0.95)	0 (0)	1 (0.18)	0 (0)	7 (0.64)	0 (0)
Hypertension						
No	724 (98.1)	798 (96.49)	547 (97.16)	722 (97.3)	1069 (98.07)	1073 (95.63)
Yes	7 (0.95)	29 (3.51)	15 (2.66)	19 (2.56)	14 (1.28)	49 (4.37)
Unknown	7 (0.95)	0 (0)	1 (0.18)	1 (0.13)	7 (0.64)	0 (0)
Avg(SD)						
Prenatal visits	8.6 (4.7)	9.5 (4.9)	8.24 (5.1)	10.0(5.4)	8.9 (4.3)	9.2 (5.00)

Table 4. Maternal characteristics of HNHF and comparison areas before and after the housing investment

Table 5 displays the DID regression results from both the pooled and separate comparison models (full regression models are shown in Appendix B and C). In both the PTB and LBW models there were no significant differences between the area changes during the study period, net of all other model covariates. In fact, the positive DID estimate in each pooled model indicates HNHF (PTB =0.27; LBW = 0.06) fared worse in birth outcomes relative to the comparison areas, yet again these differences were not significant. The negative estimate for the *Post* time variable demonstrates that the probability of both PTB (-0.22) and LBW (-0.03) decreased in the pooled comparison communities over the study period. Before the intervention, the HNHF neighborhood had lower probabilities of PTB (-0.04), but higher probabilities of LBW (0.08) relative to the pooled comparison areas. However, these main effects for time and area were also not significant, net of all other model covariates.

Results were similar in the models examining comparison areas separately. Here, the positive interaction term estimate for PTB indicated that in both Comparison 1 (0.35) and Comparison 2 (0.20) probability of PTB decreased more relative to HNHF over the study period. This difference, however, was not significant. In the separate model for LBW, probability decreased more in Comparison 1 (0.33), but increased more in Comparison 2 (-0.11) relative to HNHF over the study period. Again, these estimates were not significant.

		PTB			LBW		
		Estimate	95% CI	Pr(>|z|)	Estimate	95% CI	Pr(>|z|)
Pooled	HNHF	-0.04	-0.32 - 0.24	0.78	0.08	-0.21 - 0.36	0.60
	Post	-0.22	-0.44 - 0.01	0.06	-0.03	-0.26 - 0.2	0.79
	HNHF* Post	0.27	-0.11 - 0.64	0.16	0.06	-0.32 - 0.44	0.74
Comparison 1	HNHF	0.03	-0.32 - 0.39	0.85	-0.04	-0.39 - 0.31	0.82
	Post	-0.34	-0.72 - 0.05	0.09	-0.36	-0.74 - 0.02	0.06
	HNHF* Post	0.35	-0.13 - 0.84	0.15	0.33	-0.15 - 0.82	0.18
Comparison 2	HNHF	-0.06	-0.38 - 0.25	0.69	0.18	-0.14 - 0.51	0.26
	Post	-0.15	-0.42 - 0.13	0.30	0.18	-0.11 - 0.46	0.22
	HNHF* Post	0.20	-0.21 - 0.61	0.34	-0.11	-0.53 - 0.3	0.59

Table 5. Adjusted Difference-in-Differences estimates of PTB and LBW probability. All estimates include controls for maternal race, education, age, smoking status, BMI, Medicaid enrollment, previous preterm birth, hypertension, and # prenatal visits

Predictive probabilities were also calculated for each model (Figures 7 and 8). The odds of PTB increased for HNHF (0.005), while the odds decreased for the pooled comparison areas (0.02); however, these differences are not significant and can be attributed only to random chance alone. In examination of the comparison areas separately against the HNHF neighborhood, it is evident that this difference is largely driven by our Comparison 1 neighborhood. In the Comparison 1 area the odds of PTB decreased by 0.027, while the probability in the Comparison 2 area only decreased by 0.013.

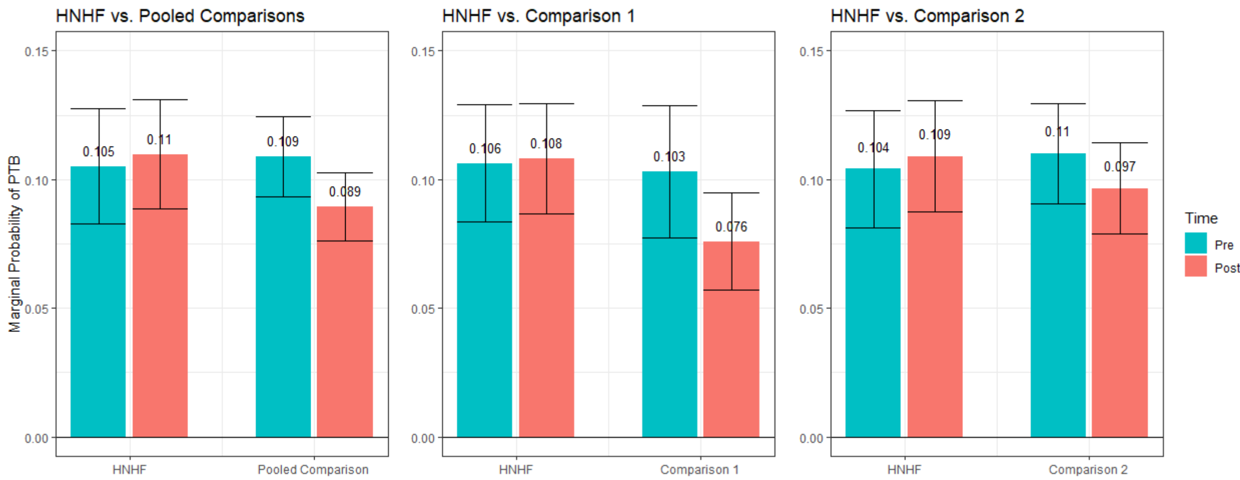

Figure 7. Predicted probabilities of preterm birth before and after the HNHF intervention for each DID regression model

The odds of LBW increased for HNHF (0.003) after the intervention, while again, the pooled comparison areas saw a decrease in probability (0.003). However, in the separate comparison area models, the increase in odds was greater for Comparison 2 (0.015). Further, in the LBW models, our comparison areas had opposite effects, and their pooled estimate negate their individual effects. In the separate adjusted model for Comparison 1, there was a slight insignificant decrease in LBW probability. However, all differences in these models were not significant and are attributed only to random chance alone.

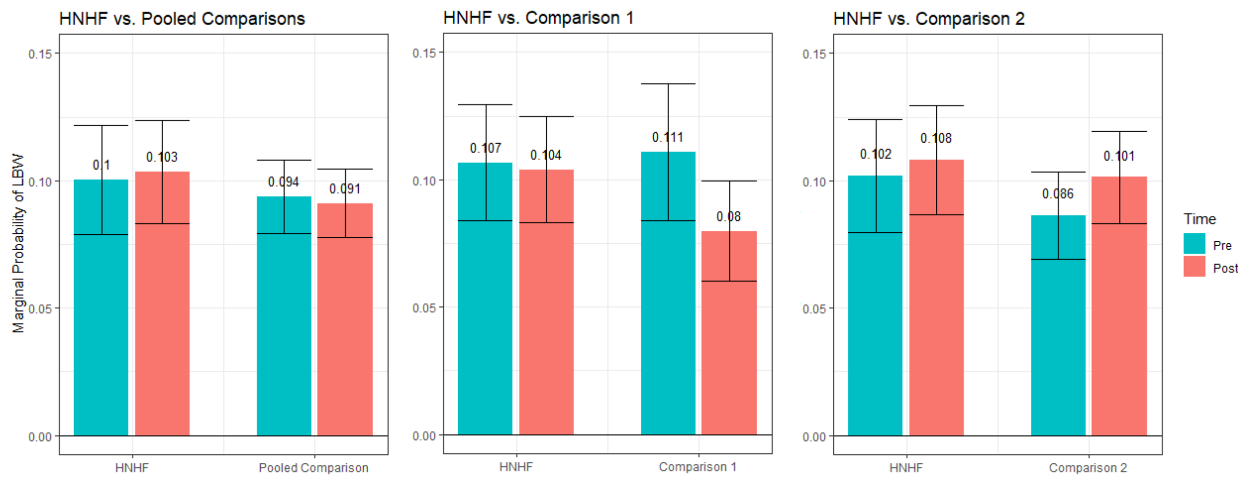

Figure 8. Predicted probabilities of low birthweight before and after the HNHF intervention for each DID regression model

Robustness checks using the pre-defined sensitivity analysis tract aggregations confirmed our findings. DID estimates were insignificant for both outcomes in each tested neighborhood definition.

Discussion

This analysis contributes to the field of neighborhood health through the development of a comparison selection methodology that is applicable to other neighborhood-level quasi-experimental studies where randomization of subjects is not feasible. Utilizing conceptually relevant neighborhood-level context measures beyond Census variables reduces bias and threats to internal validity that are often limitations of quasi-experimental study designs. Although our study specifically examined changes in PTB and LBW, the methodology is applicable to a host of other potential outcomes.

In addition to method development, this study sought to analyze effects from a neighborhood-level housing investment on two birth outcomes. The results from this analysis demonstrate the HNHF initiative had insignificant marginal effects on the probability of PTB or

LBW for Southside mothers. There were no significant area birth outcome differences over the study period in any of the tested models. Further, the overall individual probabilities in the full-tract model increased more in the HNHF treatment area relative to the two selected comparison communities, for both PTB and LBW outcomes. Relative to Comparison 2, LBW probability did increase at a slower rate, but this difference was not significant. These results do not support our original hypothesis that the affordable housing investment would "spillover" to other residents in the neighborhood and decrease adverse birth outcomes.

There are a few explanations for why our hypothesis was incorrect. Generally, neighborhood effects are weaker or more mixed in methodologically stronger study designs (Schmidt et al., 2018). The HNHF initiative was also an unfocused housing investment at the neighborhood-level. A majority of investment has occurred primarily in only two of ten census tracts, but a sensitivity analysis (Sensitivity Aggregation 3 in Appendix A) examining these high-density investment tracts confirmed the insignificant findings in the larger tract aggregation models. It is possible that spillover effects were localized to geographies smaller than a census tract. Further, we cannot separate impacts by investment type. The extent of impact may be different between homeowner repairs, full gut rehabs, or affordable rentals.

It is also possible that it is too early to see significant results from the investment, as it may take longer than the current study period to reverse the lifelong cumulative impact of social inequality, structural racism, or poverty. Stress-inducing pathways that are hypothesized to affect birth outcomes likely begin before a mother's pregnancy. Life course perspective posits PTB and LBW outcomes result from differential exposures to protective and risk factors throughout the course of a mother's life (Lu & Halfon, 2003). Additionally, the original efforts of HNHF were focused on homeownership. Only within the last few years did they expand investment into affordable rentals. Renter and homeowner populations are likely different and housing stability impacts may be more beneficial for those who rent. Conclusions in future evaluations may change due to a longer study interval, as well as an increase in investment of affordable rentals. To influence birth outcomes, the incorporation of individual investment may also be warranted. It could be that coupling of individual and neighborhood-level efforts are needed to combat adverse birth outcomes.

Finally, there are always limitations using vital birth records in a secondary analysis. Prenatal care was missing for approximately 14% of the study sample and these births were ultimately excluded. It is likely this data is missing simply because mothers did not have prenatal care. This exclusion could potentially introduce selection bias in our study results. Other variables were also limited in their completeness and were coded as dummy variables so as not to lose statistical power.

It is also important to note limitations in the development of our method. Our specific result was limited by the clustering of census tracts as the primary geography. Although data is commonly available at the tract level, Census boundaries are arbitrary and can produce issues of spatial misclassification (Duncan, Kawachi, Subramanian, Aldstadt, Melly & Williams, 2013). Further, residents may not spend time in all parts of a given tract or may move beyond these boundaries in daily life (Kwan, 2012). Future analysis should test alternative geography definitions, such as census blocks, GIS-based buffers, or activity spaces, if data at each level is available.

We also experienced issues related to model power when incorporating census tracts. As Columbus is a relatively small city in terms of population, there were only 284 tracts for analysis and only 10 of these had received the HNHF investment. Additional variables relevant to neighborhood context were available, such as school performance, food environment, and other housing attributes from the parcel data. When we tried to incorporate these variables into the model, we experienced convergence issues. Moreover, the propensities for many of the matched tracts were lower, indicating the combination of factors was unique in the Southside compared to other neighborhoods in Columbus. Although we only included tracts with given propensities and evaluated multiple neighborhood definitions in a sensitivity analysis, our aggregation of tracts was subjective. This method may work better for interventions with more census tracts of investment, in larger U.S. cities with greater population density, or using census blocks, which would allow for more model power.

Overall this analysis provides a unique framework for evaluating quasi-experimental studies. Although we did not see significant differences in birth outcomes, due to the multiple pathways housing affects health, other outcomes should be assessed. Outcomes that have more direct associations to housing, such as asthma or lead poisoning, could potentially have significant decreases in prevalence.

CHAPTER 3: CONCLUSION AND DISCUSSION

This thesis represents an important addition to the growing body of literature on neighborhood health methodology. My first research objective was to understand the social, economic, and political constructs of the Southside that contribute to neighborhood effects, using a neighborhood political ecology framework. My analysis found that Columbus's Southside has experienced decades of abandonment that has resulted in high vacancy, high housing instability, and a deteriorating housing stock. Abandonment processes include population and economic loss in the central city, racial discrimination in mortgage lending, as well as racial segregation throughout history. These insights, in conjunction with other conceptually relevant variables, were used to inform selection of neighborhood context variables, for a deeper understanding of place. A novel component of analysis was collecting multiple local-level variables for identification of a comparable neighborhood in Columbus through propensity score modeling. Although neighborhood effects are well documented in literature, a need for inclusion of variables beyond traditional Census measures, such as socioeconomic status, has been noted.

Unfortunately, the abandonment of the central city, as well as racial discrimination and segregation, is not unique to Columbus. This method has the potential for use in other neighborhood-level analyses and metropolitan areas across the United States. The variables that were included in the propensity score modeling were publicly available and could be easily accessed and analyzed. Although data was not available in our analysis, inclusion of local resident perceptions or other subjective factors could even further define place. Using this method to assess experimental studies would help reduce bias and bolster causal inference in the field of neighborhood health.

In order to address my second research objective, I hypothesized that the HNHF investment in the housing stock of the Southside would reduce the disproportionately high rates of preterm birth and low birthweight in the neighborhood. This hypothesis was developed based on a literature review outlining the effects of place on health and the fact that increases in maternal stress from distressed neighborhoods can induce early delivery, decrease overall maternal health, or promote unhealthy behaviors for pregnancy. The results of the DID analysis did not support my hypothesis. There were no significant differences in any of the tested models. Although these differences were not significant, in certain aggregations of tracts, the probability of PTB or LBW increased more relative to the comparison areas. This finding implies that the current investment strategy by HNHF alone is insufficient to fully address birth outcomes disparities, highlighting the need for incorporation of individual-level investment as well. It also suggests that spillover effects from current HNHF investment strategies may be limited to geographies smaller than census tracts. The Southside has experienced decades of disinvestment. It is also possible that not enough time has passed to reverse these engrained effects. Future research evaluating the HNHF investment should examine geographies smaller than a tract, such as census blocks, to see if there are any changes in results, as well as revisit this analysis once more time has passed.

Although results of this analysis were insignificant, HNHF efforts have not been in vain. Since the beginning of the investment, notable reductions in both crime and vacancy rates have occurred (Kelleher et al., 2018). Improved housing also has the potential to reduce a variety of other health outcome disparities for both children and adults. Future evaluations should also explore the impact of HNHF on these outcomes, specifically those that may have a more direct hypothesized relationship with housing, such as asthma or lead exposure.

There are a few recommendations for HNHF model improvement in future neighborhood development work. HNHF data included only parcel location and investment type. Comprehensive data collection at baseline and follow up for impacted individuals, including subjective measures, would facilitate improved evaluation of specific investment strategy impacts. Collection of residential history for these individuals would also aid in analyses of neighborhood change or residential displacement. Finally, as the HNHF strategy was unfocused, future work should plan investment strategies based on the health outcomes they are interested in analyzing.

The HNHF initiative is an innovative model for neighborhood development and is timely as re-urbanization occurs in many metropolitan areas. The national movement back to cities has increased demand for safe and affordable housing across all incomes and ages. In the Southside, HNHF has shifted their priority from homeownership to affordable rental strategies, as increasing rents and competition are expected to affect low-income renters disproportionately. In 2016, 83% of low-income renters were considered cost-burdened (Joint Center for Housing Studies, 2017). Cost-burdened renters are at a greater risk for housing instability, including eviction, homelessness, or forced moves. With an expected increase in competition for already scarce affordable units, future directions in neighborhood development and health should explore how this movement impacts healthcare utilization and outcomes for these residents. Better measures are also needed to examine processes such as gentrification and residential displacement. Finally, as more individuals across all demographics delay or forgo the "American

Dream" of homeownership, future studies should examine how this shift affects neighborhood stability, social structure, and overall health.

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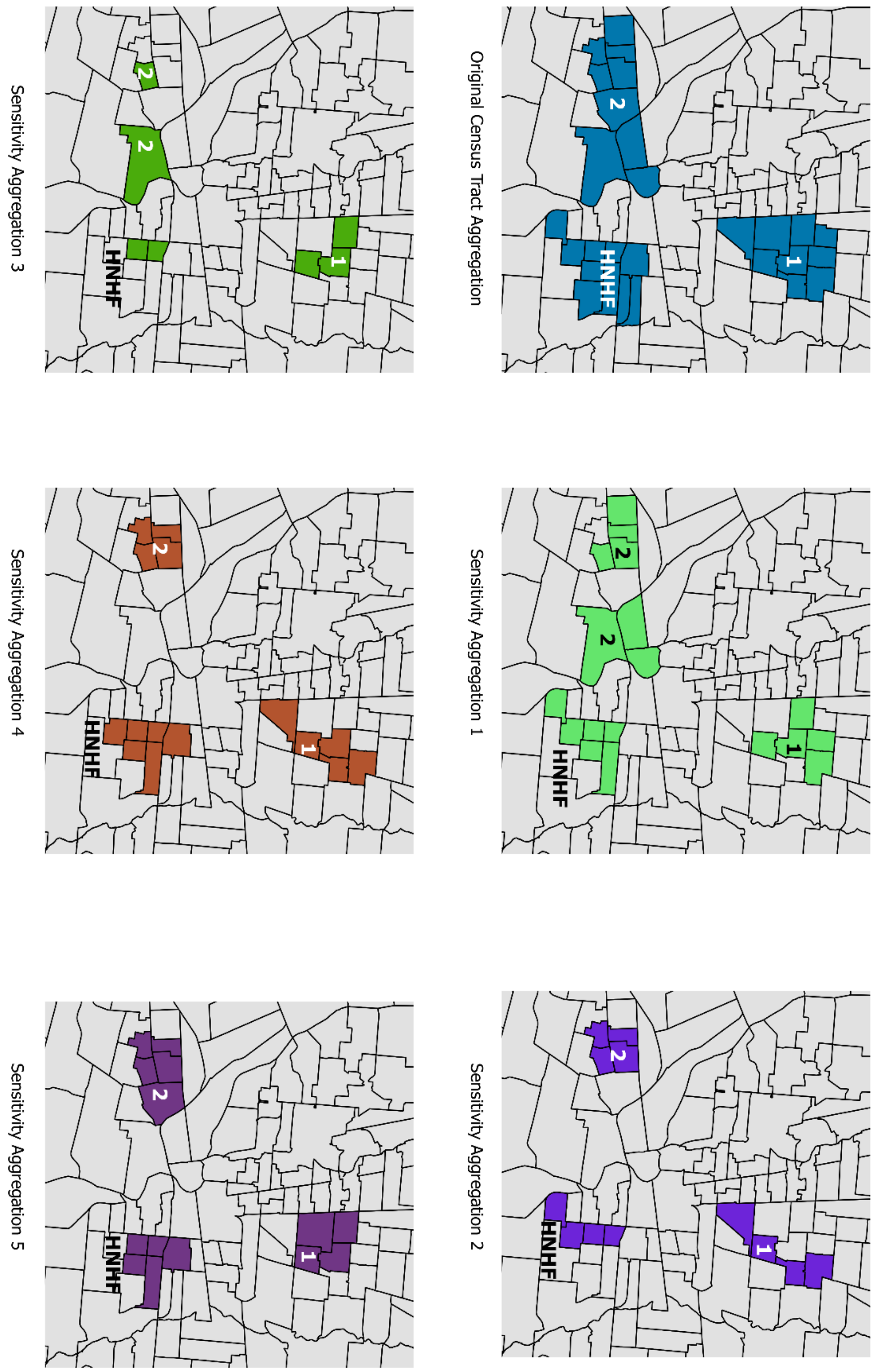
APPENDIX A. SENSITIVITY ANALYSIS ALTERNATIVE NEIGHBORHOOD DEFINITIONS



APPENDIX B. DID LOGISTIC REGRESSION ANALYSIS OF PTB TOTAL TRACT ANALYSIS USING POOLED AND SEPARATE COMPARISON AREAS

	Preterm Birth Models								
	Pooled			Comparison 1			Comparison 2		
	Estimate	**95% CI**	**Pr(>|z|)**	**Estimate**	**95% CI**	**Pr(>|z|)**	**Estimate**	**95% CI**	**Pr(>|z|)**
Intercept	-1.71	-2.05 - -1.36		-1.53	-2.01 - -1.05	0.00	-1.71	-2.12 - -1.3	0.00
Maternal race									
White	Reference			Reference			Reference		
Black	0.29	0.09 - 0.49	0.00	0.27	-0.01 - 0.55	0.05	0.29	0.06 - 0.53	0.02
Other	-0.06	-0.43 - 0.31	0.75	-0.09	-0.66 - 0.48	0.76	-0.09	-0.51 - 0.33	0.68
Maternal Education									
More than HS	Reference			Reference			Reference		
HS	0.31	0.06 - 0.56	0.01	0.27	-0.05 - 0.58	0.10	0.31	0.02 - 0.61	0.04
Less than HS	0.34	0.09 - 0.6	0.01	0.16	-0.17 - 0.5	0.34	0.38	0.08 - 0.67	0.01
Unknown	0.37	-0.27 - 1	0.26	0.77	0.03 - 1.5	0.04	-0.68	-1.74 - 0.39	0.21
Age									
> 20	-0.09	-0.37 - 0.19	0.54	-0.16	-0.56 - 0.24	0.44	-0.08	-0.39 - 0.24	0.64
20-24	-0.15	-0.36 - 0.07	0.18	-0.07	-0.35 - 0.22	0.65	-0.21	-0.46 - 0.04	0.10
20-34	Reference			Reference			Reference		
35-39	0.57	0.25 - 0.9	0.00		0.28 - 1.13	0.00	0.55	0.17 - 0.93	0.00
40+	0.49	-0.16 - 1.15	0.14	0.51	-0.31 - 1.32	0.22	0.56	-0.23 - 1.34	0.16
Smoking Status									
No	Reference			Reference			Reference		
Yes	0.07	-0.13 - 0.27	0.47	0.08	-0.2 - 0.35	0.59	0.06	-0.16 - 0.29	0.59
Unknown	-0.69	-1.38 - 0	0.05	-0.40	-1.15 - 0.35	0.29	-0.72	-1.59 - 0.15	0.10
BMI									
Underweight	0.44	0.09 - 0.8	0.01	0.21	-0.3 - 0.72	0.42	0.48	0.1 - 0.87	0.01
Healthy	Reference			Reference			Reference		
Overweight	0.06	-0.18 - 0.3	0.61	-0.14	-0.48 - 0.2	0.42	0.15	-0.11 - 0.42	0.26
Obese	-0.1	-0.34 - 0.13	0.38	0.00	-0.3 - 0.31	0.99	-0.30	-0.58 - -0.02	0.03
Unknown	0.14	-0.2 - 0.49	0.41	-0.10	-0.56 - 0.35	0.66	0.16	-0.25 - 0.57	0.44
Medicaid									
No	Reference			Reference			Reference		
Yes	-0.09	-0.3 - 0.12	0.42	-0.16	-0.44 - 0.11	0.25	-0.09	-0.33 - 0.16	0.50
Unknown	-0.58	-1.35 - 0.19	0.14	-0.57	-1.41 - 0.28	0.19	-0.42	-1.32 - 0.47	0.35
Previous Preterm									
No	Reference			Reference			Reference		
Yes	1.11	0.86 - 1.36	< 2e-16	1.25	0.93 - 1.58	0.00	1.16	0.87 - 1.45	0.00
Unknown	0.92	-0.21 - 2.06	0.11	1.20	-0.34 - 2.73	0.13	1.01	-0.16 - 2.18	0.09
Hypertension									
No	Reference			Reference			Reference		
Yes	0.48	-0.01 - 0.96	0.05	0.74	0.12 - 1.37	0.02	0.20	-0.4 - 0.8	0.51
Unknown	0.92	-0.21 - 2.06	0.11	1.20	-0.34 - 2.73	0.13	1.01	-0.16 - 2.18	0.09
Prenatal Visits	-0.09	-0.11 - -0.07	< 2e-16	-0.10	-0.13 - -0.08	0.00	-0.08	-0.1 - -0.06	0.00
HNHF	-0.04	-0.32 - 0.24	0.78	0.03	-0.32 - 0.39	0.85	-0.06	-0.38 - 0.25	0.69
Time	-0.22	-0.44 - 0.01	0.06	-0.34	-0.72 - 0.05	0.09	-0.15	-0.42 - 0.13	0.30
HNHF:Time	0.27	-0.11 - 0.64	0.16	0.35	-0.13 - 0.84	0.15	0.20	-0.21 - 0.61	0.34

APPENDIX C. DID LOGISTIC REGRESSION ANALYSIS OF LBW TOTAL TRACT ANALYSIS USING POOLED AND SEPARATE COMPARISON AREAS

	Low Birth Weight Models								
	Pooled			Comparison 1			Comparison 2		
	Estimate	**95% CI**	**Pr(>|z|)**	**Estimate**	**95% CI**	**Pr(>|z|)**	**Estimate**	**95% CI**	**Pr(>|z|)**
Intercept	-2.40	-2.78 - -2.03	< 2e-16	-2.10	-2.6 - -1.6	< 2e-16	-2.56	-3.01 - -2.11	< 2e-16
Maternal race									
White	Reference			Reference			Reference		
Black	0.54	0.33 - 0.74	0.00	0.51	0.22 - 0.79	0.00	0.46	0.22 - 0.7	0.00
Other	0.07	-0.33 - 0.47	0.72	0.19	-0.39 - 0.76	0.52	-0.09	-0.55 - 0.37	0.71
Maternal Education									
More than HS	Reference			Reference			Reference		
HS	0.30	0.05 - 0.56	0.02	0.12	-0.2 - 0.43	0.47	0.38	0.07 - 0.69	0.01
Less than HS	0.28	0.02 - 0.54	0.03	0.07	-0.26 - 0.4	0.66	0.41	0.1 - 0.71	0.01
Unknown	0.17	-0.52 - 0.86	0.62	0.23	-0.61 - 1.07	0.59	-0.11	-1.01 - 0.79	0.82
Age									
> 20	-0.08	-0.37 - 0.21	0.59	-0.06	-0.46 - 0.33	0.75	-0.08	-0.4 - 0.25	0.64
20-24	0.03	-0.19 - 0.24	0.80	0.10	-0.18 - 0.39	0.47	-0.02	-0.26 - 0.23	0.88
20-34	Reference			Reference			Reference		
35-39	0.40	0.04 - 0.76	0.03	0.52	0.07 - 0.97	0.02	0.31	-0.12 - 0.74	0.16
40+	0.32	-0.4 - 1.04	0.39	0.10	-0.84 - 1.03	0.84	0.59	-0.22 - 1.4	0.15
Smoking Status									
No	Reference			Reference			Reference		
Yes	0.49	0.3 - 0.69	0.00	0.47	0.21 - 0.73	0.00	0.49	0.26 - 0.71	0.00
Unknown	-0.23	-0.88 - 0.43	0.50	-0.31	-1.09 - 0.47	0.44	-0.31	-1.11 - 0.5	0.46
BMI									
Underweight	0.63	0.3 - 0.95	0.00	0.43	-0.02 - 0.89	0.06	0.48	0.11 - 0.85	0.01
Healthy	Reference			Reference			Reference		
Overweight	-0.17	-0.41 - 0.07	0.16	-0.22	-0.55 - 0.1	0.18	-0.17	-0.44 - 0.11	0.23
Obese	-0.52	-0.76 - -0.27	0.00	-0.43	-0.75 - -0.12	0.01	-0.64	-0.93 - -0.35	0.00
Unknown	-0.39	-0.79 - 0	0.05	-0.53	-1.02 - -0.03	0.04	-0.33	-0.79 - 0.12	0.15
Medicaid									
No	Reference			Reference			Reference		
Yes	0.28	0.05 - 0.51	0.02	0.25	-0.05 - 0.54	0.10	0.31	0.04 - 0.59	0.03
Unknown	-0.23	-1 - 0.54	0.56	-0.25	-1.1 - 0.6	0.56	-0.22	-1.19 - 0.75	0.65
Previous Preterm									
No	Reference			Reference			Reference		
Yes	0.64	0.37 - 0.91	0.00	0.94	0.6 - 1.27	0.00	0.50	0.18 - 0.82	0.00
Unknown	0.60	-0.6 - 1.8	0.32	0.74	-0.94 - 2.41	0.39	0.72	-0.5 - 1.95	0.24
Hypertension									
No	Reference			Reference			Reference		
Yes	0.78	0.31 - 1.26	0.00	0.88	0.25 - 1.5	0.01	0.42	-0.17 - 1.02	0.16
Unknown	0.60	-0.6 - 1.8	0.32	0.74	-0.94 - 2.41	0.39	0.72	-0.5 - 1.95	0.24
Prenatal Visits	-0.07	-0.09 - -0.05	0.00	-0.07	-0.09 - -0.04	0.00	-0.06	-0.08 - -0.03	0.00
HNHF	0.08	-0.21 - 0.36	0.60	-0.04	-0.39 - 0.31	0.82	0.18	-0.14 - 0.51	0.26
Time	-0.03	-0.26 - 0.2	0.79	-0.36	-0.74 - 0.02	0.06	0.18	-0.11 - 0.46	0.22
HNHF:Time	0.06	-0.32 - 0.44	0.74	0.33	-0.15 - 0.82	0.18	-0.11	-0.53 - 0.3	0.59