Brownfields redevelopment and gentrification:
A socio-economic evaluation of the EPA Brownfields Pilot Program

by

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ABSTRACT

The purpose of this study to answer the question of whether the Environmental Protection Agency's Brownfields Pilot Program unintentionally contributed to the gentrification of areas near brownfield redevelopments. Using Smith's (1979) rent-gap theory, this study hypothesizes that investment in redeveloping brownfields results in a socio-economic change within areas near redeveloped brownfields. Specifically, the change involves the in-migration of higher income residents and the out-migration of minority and low-income residents. To test this hypothesis, this project used a two part methodology to study EPA Region7: 1) a cross-sectional analysis and two-sample t-tests measured the extent of environmental injustice near brownfields prior to receiving funding; and 2) involved a longitudinal analysis and MANCOVA to investigate the changing socio-economic character of areas near brownfields following redevelopment. By using 1990 Census data at the block group level, the cross-sectional analysis provided evidence of environmental injustice within a 0.5 mile buffer of brownfields. The longitudinal analysis, using data from the 1990 and 2000 Census, and the 2009 American Community Survey 5-year estimates, found that the changes observed in 10 socio-economic variables does not provide evidence of gentrification. In conclusion, funding provided by the EPA Brownfields Pilot Program in Region 7 did not result in the gentrification of areas surrounding brownfield redevelopments.

CHAPTER 1: INTRODUCTION

1.1 Motivation

The Environmental Protection Agency (EPA) estimates the number of brownfields located in the U.S. to be between 500,000 and 1,000,000 (U.S. Conference of Mayors 2008). Richard Longworth (2008) states the problem of this abundance of brownfields quite clearly, "Many industrial towns and cities are left now with the abandoned hulls of old factories, rusting away on land poisoned by generations of pollution, probably unsellable, certainly of no use to any twenty-first century investor." (p. 255). This reveals the significance of research into brownfields redevelopment because of the great opportunity that many cities have in the revitalization of their once thriving central city (Cunningham 2002).

The EPA has been at the forefront in the effort to clean up and redevelop brownfields, beginning with the EPA Brownfields Pilot Program (EPA-BPP). This program started in 1993 and awarded $200,000 to each city that exhibited distressed urban areas resulting from environmental contamination. Through EPA funding, cities were able to assess the extent of contamination and begin plans for cleanup and redevelopment. Between 1993 and 2001 the EPA awarded 184 pilot grants and helped to revitalize blighted urban centers (Solitare and Greenberg 2002). The EPA-BPP was evaluated as a success and in 2002 the pilot program became a federal funded program under the Small Business Liability Relief and Brownfields Revitalization Act (commonly referred to as Brownfields Law).

Although the EPA-BPP was deemed a success by local governments who saw their once dilapidated urban areas become prosperous again, the EPA was concerned with some unintended consequences of the EPA-BPP. One of those concerns was that the EPA-BPP

unintentionally contributed to the phenomena of gentrification (EPA 2009a). Through investment in the redevelopment of urban areas, the EPA was concerned that low-income and minority residents were not benefiting from the enhanced environmental conditions but were instead being displaced by higher-income residents. Various researchers have investigated the relationship between clean-up and redevelopment of contaminated sites and gentrification, but by using a relatively short-time frame analysis (10 years) (Eckerd 2010; Essoka 2010; and Pearsall 2010). Clean up and redevelopment of brownfields is a slow process and on average takes approximately 5 years for a brownfield to be assessed, cleaned up and redeveloped (U.S. Conference of Mayors 2008). Thus, it would seem that a longer time frame analysis would better capture the outcomes of brownfield redevelopment. The EPA's concern of gentrification that may have been caused by the EPA-BPP is the focus of this study. Through the use of a 19 year time-frame analysis, this study is intended to examine possible relationship between brownfield redevelopment and gentrification.

1.2 Brownfields and the Environmental Protection Agency

When defining the term brownfield, the majority of researchers refer to the definition provided by the EPA. The EPA first defined brownfields in the early 1990s and the definition is slightly different than the currently used definition under Brownfields Law. The 1990s EPA definition of brownfield was "abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination that can add cost, time and uncertainty to a redevelopment project" (Cunningham 2002, p. 134). In the 2002 Brownfields Law (Small Business Liability Relief and Brownfields Revitalization Act of 2002), a brownfield is defined as "real property,

the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" (EPA 2009b). Although slightly different in their wording, both definitions emphasize the influence of environmental contamination on hindering redevelopment. This study uses the 1990s definition since the brownfields under investigation were part of the EPA-BPP prior to the implementation of Brownfields Law.

The federal government first attempted to clean up contaminated sites through the 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Also known as Superfund, CERCLA has been scrutinized for hindering the redevelopment of contaminated sites because it did not address the liability issues associated with purchasing and developing contaminated sites. Under CERCLA, the liability of environmental hazards was based on the status of ownership rather than the extent to which the individual caused the contamination (Kushner 2006). This created a disincentive for developers to purchase properties that were possibly contaminated.

Considering the problems associated with development of contaminated sites under CERCLA, the EPA initiated the EPA Brownfields Pilot Program (EPA-BPP) in 1993. The term brownfields was introduced shortly prior to the EPA –BPP when researchers and practitioners realized the downsides of environmental regulatory frameworks (e.g. CERCLA) that were intended to protect the environment, but were actually hindering the redevelopment of former industrial and commercial sites (Hollander et al. 2010). The term brownfield was invented because it does not bring to mind the negative connotations associated with terms such as "contaminated" or "derelict," and because it represents a counterpart to greenfield, a term describing undeveloped land on the edge of urban centers (DeSousa 2005).

The pilot program was an attempt by the EPA to ease the process of brownfield redevelopment by providing funding for a grant recipient to inventory sites, prioritize sites, assess sites, conduct redevelopment planning, and create community involvement (EPA 2009a). The program was created to assist in the cleanup of contaminated properties that are not so severely contaminated that they could be placed on the National Priorities List under CERCLA. EPA-BPP grants were not intended to fund cleanup or redevelopment so cities that received pilot grants had to find alternative funding sources (e.g. EPA cleanup grants or EPA revolving loan fund grants). The EPA-BPP was praised for alleviating some of the liability issues of CERCLA and also providing a faster process for which contaminated sites could be redeveloped (Hollander et al. 2010). With the passage of the Small Business Liability Relief and Brownfields Revitalization Act in 2002, the EPA-BPP became a federal legislatively created and funded program. What was once designated the EPA-BPP became simply known as the EPA Brownfields Program (Kubasek and Silverman 2008).

1.3 The Origin of Brownfields

The EPA initiated CERCLA and the brownfield pilot program because of the great abundance of underutilized and contaminated properties that began to deteriorate once thriving urban centers. The origin of brownfields can be traced to the declining industrial and manufacturing significance of U.S. cities (Hudson 1987) and the migration of industries from industrialized cities to greenfield areas or abroad (DeSousa 2005). The migration of industries in the years following World War II can be attributed to industries following the exodus of the labor force to the suburbs and also the desire to acquire cheaper land and improved infrastructure in the suburbs (DeSousa 2005). Since the end of World War II, one

of the major shifts has been the redistribution of population, commerce, and industry from the urban core to the suburbs (Lang 1982). This shift was most prevalent in the Northeast and Midwest regions of the U.S. (Hudson 1987).

The decreased significance of the industrial and manufacturing sectors of the U.S. economy can also be attributed to the economic shift from Fordism to a post-Fordist system (Bonanno and Constance 1996). The Fordism concept was inspired Henry Ford's assembly line and is characterized by a system of mechanized mass production and rigid managerial structure that reached its peak in the 1950s and 1960s (Bonanno and Constance 1996). The transition to a post-Fordist system was the result of increased competition from foreign markets (due to globalization) and the ability of firms to use global sourcing to seek the least expensive means of production. Following the end of the post World War II population boom and the oil shocks of the mid 1970s, the ability of manufacturing firms to make profits diminished and they began to seek new forms of production powered by cheap labor (Bonanno and Constance 1996). Manufacturing and industrial firms began to re-locate to other countries that could provide cheap labor and facilities. This globalization of U.S. industries was also a contributing factor to the abandonment of archaic Fordism manufacturing facilities that are now considered brownfields.

As the industrial sector in cities diminished after the 1970s, the properties that once housed industrial and manufacturing facilities were abandoned. The problem with abandoning these once productive facilities is that many of the industries produced waste on-site and following the abandonment of the property, the waste is left behind to potentially contaminate adjacent properties. The reality for many major manufacturing and industrial cities in the late 1970s was a pattern of economic decline in the urban centers, leading to

abandonment and subsequent blight of urban centers (Lang 1982) and thus the creation of brownfields.

1.4 Significance of Brownfields

In addition to the large number of brownfields and potential for economic gains through redevelopment, the health hazards associated with contaminated sites is also a contributing factor to the importance of redeveloping brownfields. Environmental contamination and the exposure of residents to human health hazards was one of the primary concerns the EPA attempted to address when developing the EPA-BPP (EPA 2009b). The successful clean up and redevelopment of brownfields has the potential to create a healthy environment that can enhance the livability of communities once threatened by environmental contamination. Brownfields are also associated with other risks to area residents, such as trash, vermin, falling structures, fires, and attraction of crime (Arnold 2007). These risks and the upside associated with clean up provide yet another reason why brownfields redevelopment is important to the urban planning arena.

More recently, brownfields redevelopment has received attention because of its potential to be a smart growth strategy. Brownfield redevelopment revitalizes once prosperous inner cities and decreases the need to annex greenfield sites located on the edge of metropolitan areas (Greenberg et al. 2001). Unlike the development of greenfields (land that has not seen development) brownfields offer a more sustainable land-development choice (Hollander 2010). Due to the benefits of utilizing existing urban infrastructure, brownfields redevelopment has been thought of as a smart growth strategy and as stated by Greenberg et al. (2001), "…brownfields redevelopment appears to be the smartest smart

growth policy in the U.S." (p. 140). In addition, Wernstedt et al. (2004) provides a similar conclusion when describing the importance of brownfield redevelopment: "The remediation and reuse of brownfield sites provides an opportunity to both reverse the decay of already developed areas and slow unsustainable development trends throughout the country" (Wernstedt et al. 2004, p.4).

In addition, there are economic benefits that can be received by residents of communities who redevelop brownfields. Benefits to communities in close vicinity to brownfields include: improved infrastructure, reduced soils and water contamination, improved public safety, and increased municipal tax-base by removing abandoned lots. There is also the potential for job creation for local residents (Teelucksingh 2007). Given the previously mentioned benefits, brownfield redevelopment is viewed as a win-win development strategy (Wernstedt et al. 2004). If brownfields redevelopment is not done, communities which are negatively impacted by brownfields will continue to deteriorate and see an exodus of workers and jobs to the suburbs or other states or counties (Rafson and Rafson 1999).

1.5 Research Objectives and Questions

As a result of financial investments in the improvement of environmental conditions associated with brownfields, low-income populations are often replaced with wealthy in-migrants. The relationship between this phenomenon, known as gentrification, and the EPA-BPP has been examined by several researchers using relatively short timeframe analysis (10 years). A longer timeframe examination would better capture the outcomes of brownfield redevelopment. Within this context, there is a critical need to further examine, using a longer

timeframe, the socio-economic changes following brownfields redevelopment to determine if the EPA-BPP has unintentionally contributed to environmental gentrification.

My primary research objective is to further investigate the EPA's concerns about whether the Brownfields Pilot Program has unintentionally contributed to gentrification. This study will attempt to answer three research questions:

1) Is there a relationship between brownfield sites and environmental injustice?
2) Has the EPA Brownfield Pilot Program resulted in gentrification of areas adjacent to former brownfields?
3) If gentrification has occurred, what is the spatial extent of the gentrification?

The goal of my research is to complete a study of EPA Region 7 and the long-term changes in socio-economic conditions for areas adjacent to brownfields that have received EPA Brownfield Pilot Grants. Through this research, I hope to determine whether investment in improving the environmental quality through the implementation of the EPA Brownfields Pilot Program encouraged gentrification.

1.6 Thesis Outline

This research is organized as follows. Chapter 2 introduces the theoretical framework, which is based in two theories: Tiebout's local public goods theory (1956) and Smith's rent-gap theory (1979). In addition, the conceptual framework explains the concepts to be used and the relationship between them. The literature review (chapter 3) focuses on environmental justice and gentrification, and examines past studies that have investigated the relationship between brownfields and environmental justice and gentrification. The methodology (chapter 4) describes the two part methodology (cross-sectional and

longitudinal) for investigating issues of environmental justice and gentrification. The results are presented in Chapter 5, describing the collected data and the results of the analytical tests. This thesis concludes with a discussion of the findings (chapter 6 Conclusion), the limitations of the study, and possible future studies.

CHAPTER 2: THEORETICAL & CONCEPTUAL FRAMEWORKS

This chapter introduces the theoretical framework that guides this research. The theoretical framework consists of two theories, one for explaining the emergence of environmental justice (Tiebout 1956) and the other for providing a possible explanation for the phenomena of gentrification (Smith 1979). The conceptual framework describes the concepts involved in this research and the relationship between them.

2.1 Theoretical Framework

With the goal of this research to determine if there is a relationship between brownfields redevelopment and the gentrification, the issue of environmental justice must first be addressed. If it is indeed the case that cleanup of brownfields results in gentrification, it follows that in order for the area adjacent to the brownfield to become gentrified, low-income and minority residents must first have occupied the area.

2.1.1 Tiebout's Local Public Goods Theory

The concept of environmental justice does not have a precise definition, (Solitare and Greenberg 2002) but at its core the concept is about the disproportionate impacts of environmental and land-use policies on low-income neighborhoods and communities of color (Arnold 2007). Environmental justice includes the protection of marginalized communities based on both class and race (Schlosberg 2007). The issue of environmental justice and brownfields can be explained through the use of Tiebout's theory that households decide where to live based on availability of public goods and housing costs (Tiebout 1956). Tiebout's model suggested that households select where to live based on communities providing the optimal bundle of taxes and public goods (Tiebout 1956), with environmental

quality being considered a public good. The theory explains that when a polluting facility is placed in a neighborhood, those that have the financial means move to an area where there is better environmental quality and a more preferred bundle of public goods. Low-income residents remain in the polluted area because they are willing to sacrifice environmental quality for affordable housing (Benzhaf and McCormick 2007). Benzhaf and Walsh (2008) provided evidence for this theory when they investigated how households migrate in response to environmental quality. Thus, as the facility is abandoned and the area becomes increasingly blighted with contamination, moderate to high income residents move to an area that suits their preferences and low income residents are forced to remain in an area that is potentially hazardous to their health. If Tiebout's theory holds true, it is expected that within EPA Region 7 there will be higher proportions of low-income and minority residents near contaminated brownfields since low-income residents will sacrifice environmental quality for affordable housing costs. The reverse of this demographic sorting is hypothesized to occur when the former contaminated area is cleaned up and redeveloped.

The reverse of Tiebout's theory that explains environmental justice is referred to as environmental gentrification. Environmental gentrification is based on the notion that as these contaminated sites are cleanup, the area becomes attractive to a broader range of residents and as higher-income residents move into the redeveloped area, housing prices and land values increase (Dale et al. 1999). This rise in land values places pressures on landlords to increase rental rates, which directly impacts the low-income residents that took advantage of the once low rent (Lang 1982). If the low-income and minority residents can no longer afford the increased rent, they will be forced to relocate to another area of the city that meets their needs for affordable housing.

2.1.2 Smith's Rent-Gap Theory

The second theory that is part of the theoretical framework is the rent-gap theory developed by Neil Smith in 1979. Smith's theory will be used to predict the outcomes of brownfield redevelopment and the subsequent gentrification. The term gentrification was first introduced by Ruth Glass in her description of the changing metropolitan center in London in the 1960s. Glass described gentrification as a process of invasion by middle and upper class citizens and the displacement of the working class (Benzaf and McCormick 2007 citing Glass 1964). More recent scholars have defined gentrification as "the redistribution of the housing stock to favor more affluent users" (Skaburskis 2010 p. 896), or more simply, the movement of wealthy in-migrants and lower-income out-migrants in urban neighborhoods (Rerat et al. 2010). Still others have described gentrification as "urban reinvasion", in which restoration of urban neighborhoods by the middle class leads to the invasion of residents with similar socio-economic status (Hudson 1987).

Smith's theory helps to explain the concept of increasing rent and development following cleanup of brownfields and the subsequent gentrification. In his theory, Smith relies on land and housing markets and the necessary capital investment to explain the process of gentrification (Smith 1979). The rent-gap is the difference between the capitalized ground rent (the actual economic return given the present land use) and the potential ground rent representing the maximum economic return from using the land for its best use (Less et al. 2008). Smith theorizes that as the rent-gap widens, it creates an incentive and opportunity for developers and investors to shift the land use to the most profitable land use, such as housing for upper-class residents (Smith 1979).

This theory relates directly to brownfield redevelopment and the possible explanation of gentrification following clean up. Brownfields and their adjacent properties have low capitalized ground rent due to the environmental contamination and abandonment of properties. The disinvestment of the area creates a low capitalized ground rent, but with the investment of funds provided by the EPA to assess and clean up the site, the area becomes accessible to new land uses that were not possible before because of environmental health hazards. The potential new land uses, such as high priced condominiums, create a wide gap between the capitalized and potential ground rent; thus providing an opportunity for developers to generate a profit by changing the land use of the former brownfield area. It is expected that if Smith's rent-gap theory holds true that the brownfields that received pilot grant funding during the mid-1990s will experience gentrification following redevelopment. Considering that property values are lower near brownfields, land values become severely undervalued following cleanup which increases the rent-gap between potential and capitalized ground rent. The wide rent-gap will trigger development of land uses that are geared toward more affluent residents and will lead to the gentrification of the brownfield area.

2.2 Conceptual Framework

The conceptual framework of this research is displayed in Figure 1. The diagram follows that brownfields became a major issue in urban planning as a result of the post-industrial economy and the movement of urban industries to the suburbs or other areas (such as southern regions of the U.S.) that could provide cheap labor. As the industry left the urban core of metropolitan areas, there was a restructuring of the urban area (Smith and Williams

1986) with areas becoming neglected and the abandoned facilities continuing to pollute adjacent areas. The first issue, environmental justice, is introduced at this point. The question is whether brownfields are disproportionately impacting the human health of disadvantaged communities. If Tiebout's theory holds true, it should be expected that low-income and minority populations should be found in higher proportions near contaminated brownfields. Following the determination of environmental justice issues, it follows that some municipalities (those with environmental justice issues associated with brownfields) are chosen to receive funding from the EPA so that brownfields can be cleaned up and redeveloped. The second issue of gentrification is introduced following funding. The question is whether improvement in the environmental conditions as a result of brownfield grants from the EPA results in gentrification of the areas adjacent to the former brownfield. Considering the rent-gap theory proposed by Smith (1979), it should be expected that redevelopment of the brownfield will be geared toward land uses that can generate profit, and ultimately favor higher income residents.

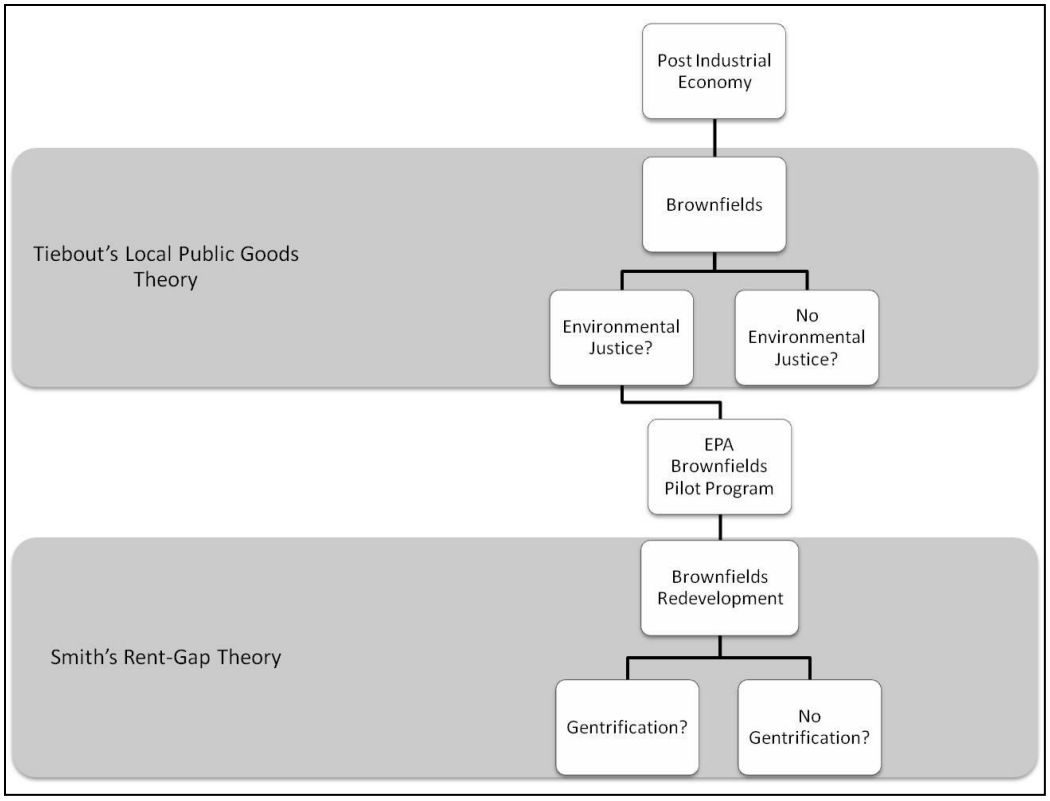

Figure 1: Conceptual Framework

The conceptual framework guides the empirical methodology of this research. As Figure 1 indicates, the first issue that must be addressed prior to determining gentrification is environmental justice. The possibility of environmental injustice will be explored by utilizing a cross-sectional study. The process of gentrification and its spatial relationship to redeveloped brownfields will be investigated using a longitudinal analysis. These approaches are further explained in chapter 4 Research Design.

CHAPTER 3: LITERATURE REVIEW

Given that the number brownfields in the U.S. is estimated to be more than 500,000 (Gallagher and Jackson 2008), the empirical literature on brownfields intersects with many disciplines and has been investigated using a wide range of methodological approaches (Wernstedt et al. 2004). This chapter reviews previous studies that have looked at the relationship between environmental justice and brownfields and also gentrification and brownfields.

3.1 Environmental Justice

The objective of environmental justice is to challenge land use policies that create unhealthy environments for disadvantaged marginalized people (Teelucksingh 2007). The first movement of environmental justice began in 1982 when residents protested the placement of hazardous waste facilities in Warren County, North Carolina. The early advocates of environmental justice were concerned with this discriminatory placement of landfills because Warren County was one of the poorest counties in the state and also a majority of the population was African American (Schlosberg 2007). This triggered the environmental justice movement in the 1980s which challenged the fairness of environmental and land use policies that resulted in the siting of hazardous waste producing facilities in low-income and minority communities (Arnold 2007). Claiming that minority and low-income neighborhoods are exposed to greater risks from environmental hazards, the movement demanded a more equitable decision making process in the siting of locally undesirable land uses (LULUs) (Been 1997).

The two landmark studies that brought to light the issues of environmental justice were the U.S. General Accounting Office (U.S.GAO) study of 1983 and the United Church of Christ's Commission for Racial Justice (UCCRJ) in 1987 (Arnold 2007). The U.S.GAO study investigated EPA Region IV and the location of four hazardous waste landfills in the region. It was found that three out of the four communities in which the landfills were located were predominately African American communities. The finding was significant because African Americans only made up about one-fifth of the population in EPA Region IV (Arnold 2007, citing U.S.GAO 1983). Following the U.S.GAO study, the UCCRJ published a study which revealed the disproportionate impact of environmental hazards on African American communities. The research found a relationship between the number of hazardous waste facilities in a zip code and the number of minorities in the zip code (UCCRJ 1987). In 1994, the UCCRJ updated its study using 1990 Census data, and again found that zip codes hosting one facility had more than twice the percentage of minorities as zip codes with no facilities (Been 1997).

The term 'justice' in environmental justice has included three dimensions of equity: distributive, recognition, and procedural (Schlosberg 2007). In his review of environmental justice literature, Schlosberg found these three forms of equity are considered in the goal of environmental justice. Distributive justice receives the most attention in U.S. environmental justice literature and is concerned with the equitable distribution of environmental risk and benefits of good environmental policy (Schlosberg 2007). Recognition justice plays an important part in the realm of environmental justice because if differences in the socio-economic status of residents are not recognized, efforts will not be made to evenly distribute the benefits of good environmental policy (Schlosberg 2007). Lastly, procedural justice is

concerned with equitable participation in the decisions of local governments (Schlosberg 2007).

When attempting to conceptualize environmental justice, there is often the consideration of three factors: economic, environmental, and process (Solitare and Greenberg 2002). The economic character of environmental justice is concerned with the equitable creation of jobs, tax base and infrastructure, while environmental concerns are about balancing the benefits and burdens of environmental health and the process deals with empowerment of the disenfranchised (Solitare and Greenberg 2002). This research will focus on the environmental factors of environmental justice, specifically, the spatial relationship between brownfields and populations of minority and low-income residents.

3.2 Environmental Justice and Brownfields

Issues associated with the spatial proximity of lower income and minority residents to brownfield sites have been framed as environmental justice problems due to the argument that brownfields disproportionately impact marginalized communities (Teelucksingh 2007). Although brownfields exist in some suburban communities, most are located in urban neighborhoods that are primarily minority and low-income residents (Gallagher and Jackson 2008). The abundance of urban brownfields is partly due to historical land use decisions that placed industrial uses next to residential areas in the central city (Solitare and Greenberg 2002). While there are few studies that specifically investigate the relationship between brownfields and environmental justice, research into this relationship is important because of two reasons. First, the environmental contamination associated with brownfields may expose inner city residents to heightened risks of human health hazards (Solitare and Greenberg

2002). Secondly, brownfields represent missed opportunities for jobs, investment, and growth in low-income communities of color. Thus, a strategy of brownfields cleanup and re-use is an environmental justice goal (Arnold 2007).

While there are studies that examine the relationship between environmental hazards (commercial hazardous waste treatment storage and disposal facilities) and environmental justice (Been 1997; Maranville et al. 2009), there are relatively few that document the spatial relationship between brownfields and environmental justice. The difference between brownfields and hazardous waste treatment storage facilities is that brownfields are often composed of abandoned facilities that are no longer in operation; but both deal with environmental contamination and the disproportionate impact to disadvantaged communities. Thus, the studies completed by Been 1997 and Maranville et al. 2009 can be related to some of the same issues commonly dealt with brownfields. Table 1 is a summary of four empirical studies that researched the relationship between brownfields, or other hazardous waste sites, and environmental justice.

Table 1: Empirical studies of contaminated sites and environmental justice

Article	Research Topic	Variables	Methodology	Results
Maranville, et al. 2009 Time Frame: 2000 Unit of Analysis: Block group	Superfund sites and Environmental Justice in IL	Percentage of minority, homeownership rate, and median household income	Used GIS to measure environmental disparity at 1,2, and 5 mile radius. Compared block groups to County using paired samples t-test	Findings support previous research that suggested race, instead of class, was the major cause of the environmental inequality.
Solitare and Greengerg 2002 Time Frame: 1990 Unit of Analysis: City	EPA Brownfields Pilot Program and Environmental Justice in the U.S.	Race and Ethnicity Family Structure Socio-economic Status Health and Safety Housing	Pilot Cities v. Nation (one-sample t-test) Pilot Cities v. States (paired samples test) Pilot Cities v. matched nonpilot cities (paired samples test)	Pilot cities are more distressed, higher unemployment rate, lower median household income, and higher poverty rates
Greenberg et al. 2000 Time Frame: 2000 Unit of Analysis: City	Brownfields and Environmental Justice in NJ	Measured per capita income, mean home value, owner occupied units, persons older than 65, persons younger than 18, and % population of White	Used GIS to collect data and compared municipalities with and without brownfields using one-way ANOVA	The municipalities without brownfields had the most affluent residents, most expensive housing, and highest proportion of white residents.
Been 1997 Time Frame: 1970-1990 Unit of Analysis: Census Tracts	Commercial hazardous waste treatment storage and disposal facilities and Environmental Justice in the U.S.	Percentage African Americans, percentage Hispanic, poverty rates, and median family income	Cross-Sectional and Longitudinal Studies: Compared means of Host tracts to means of non-host tracts using t-test	Communities with significant % of minorities were not disproportionately chosen as sites for facilities. The siting of a toxic facility does not change the ethnic or socio-economic characteristics of host communities.

Maranville et al. (2009) studied the spatial relationship between Superfund sites in Illinois and environmental justice. Specifically, the study looked at the spatial distribution of low-income and minority residents at different intervals around the Superfund site. The results of the study provide evidence and support the theory that areas adjacent to contaminated sites are disproportionately minority and low income populations. In addition, the study revealed that environmental injustices are local in nature, with decreasing disparity in demographics as one moves away from the contamination (Maranville et al. 2009). The study may provide evidence to support the theory that brownfields are associated with environmental justice issues. Although, considering that Superfund sites are larger, and more heavily contaminated than brownfields, it leaves room to question whether less publicized contaminated areas, such as brownfields, have the same spatial relationship with low-income and minority populations. A study conducted by the Council for Urban Economic Development (CUED) attempted to answer this question. The CUED looked at 107 brownfield projects around the country and revealed that areas within one mile radius of brownfield projects tend to have higher concentrations of minority populations and households below the poverty level when compared to statewide averages (Wernstedt et al. 2004 citing CUED 1999).

Another nationwide study completed by Solitare and Greenberg (2002) provides further evidence to support the findings of the CUED. Solitare and Greenberg found that EPA pilot grants typically went to communities with higher proportions of non-white households and lower median household incomes. The study shows that the EPA has recognized the problem of environmental injustice and brownfields and is attempting to alleviate the problem by awarding brownfield grants to communities with distressed central

cities and communities with large populations of minority and low-income residents. At the conclusion of their research, Solitare and Greenberg suggested that further research needs to be completed in order to evaluate whether the cities that received the assessment grants did indeed experience positive impacts as a result of EPA funding (Solitare and Greenberg 2002). This research will investigate the socio-economic impact of cities that received EPA pilot grants and assess whether gentrification is a result of EPA funding for brownfield redevelopment in EPA Region 7.

3.3 Gentrification

Although there are several definitions of gentrification, the process has a common theme of taking place in an urban context (Atkinson 2000) and being associated with the movement of elite stakeholders into existing working class and lower income city neighborhoods (Teelucksigh 2007). In addition, Benzhaf and McCormick (2007) in their review of gentrification literature have identified three hallmarks that define the term gentrification: (1) rising property values and rental costs; (2) new construction or renovation upgrading the housing stock and converting it from rental to owner-occupied units; and (3) a turnover in the local population, bringing in residents with higher socio-economic status (Banzhaf and McCormick 2007). These three hallmarks are used in this study to evaluate whether gentrification has taken place near redeveloped brownfields.

Although Smith's rent-gap theory has been used by researches who have attempted to explain the phenomena of gentrification (Eckerd 2010), there have been others that suggest that the land-use and housing markets are not the controlling factor. The process of gentrification is also thought of as a social process by which the poor will be pushed into

areas that are rejected by the affluent (Lang 1982). Following World War II, there was social trend of affluent residents moving to a suburban address. Following the trend of suburbanization of the 1950s and 1960s, the next generation of the new middle class found the urban environment to be more 'fashionable' and the market switched from low-income and minority housing in the central city to housing occupied by high-income citizens (Lang 1982). This post-industrial society has been linked to gentrification because of the greater emphasis placed on consumption, such as trendy restaurants, boutiques, and clubs, and less so on industrial production (Smith and Williams 1986).

While social factors such as the increased interest in an urban life style may influence gentrification, Smith's rent-gap theory guides this research because gentrification is often a secondary process triggered by urban renewal or urban reinvestment (such as investment in brownfield redevelopment) (Skaburskis 2010). The investment in urban centers results in increased land values and pressures developers to change land uses to ones that will generate the most profit. If the upgraded land use favors higher income residents, then it is often the case that gentrification follows. As Skaburskis (2010) notes, the redistribution of the housing stock to favor higher socio-economic residents was preceded by the pollution of the inner city which resulted in the out-migration of the middle class and the in-migration of poor immigrants who took advantage of lower housing values (Skaburskis 2010). Some scholars have defined the redistribution of housing stock, or the in-migration of high-income residents, that is stimulated by improvement to environmental conditions as environmental gentrification (Eckerd 2010). The concept of environmental gentrification is based on the idea that prior to the improvement in environmental conditions, low-income and minority

populations are disproportionately exposed to hazards that are detrimental to human health (Eckerd 2010).

Although the process of gentrification has been seen to negatively impact low-income and minority residents by forcing them to relocate to other areas of the city with affordable housing, such as near polluting facilities, there are some scholars who have found gentrification to be a social benefit. Some advocates of economic growth claim that gentrification is often associated with urban revitalization and the growth of the central city as a result of reinvestment, and benefits will trickle down to low-income residents. These benefits include an improved physical environment and job creation as a result of economic growth in the central city (Baily and Robertson 1997). Lang (1982) has also found that the process of gentrification is a 'unique vehicle for urban revitalization' (p. 2) in which local tax base increased and there is an increase in security and local prestige.

3.4 Gentrification and Brownfields

Gentrification is associated with brownfield redevelopment because it is often the case that when local governments create indicators to track the progress of redevelopment, measures on the social impacts of redevelopment are not included. Indicators are primarily economic (Pearsall 2010). Local governments often ignore or neglect social impacts because such input into redevelopment plans may result in requirements that slow real estate contracts and diminish profit margins (Wernstedt et al. 2004). DeSousa (2005) conducted a study of 24 private and public sector brownfield redevelopment stakeholders and found that economic factors are placed ahead of environmental remediation as an indicator of successful brownfield remediation. In addition, Lange and McNeil (2004) surveyed 228 EPA

brownfield pilot-grant stakeholders and found that long-term jobs and an increase in the local tax base ranked one and two in defining a successful brownfield redevelopment; whereas environmental clean-up ranked seventh. This trend toward revitalizing brownfields for the purpose of economic gain may be in conflict with the EPA Brownfield Grant Program's goal of revitalizing the social, economic, and environmental conditions of communities affected by contaminated sites. The trend toward redeveloping brownfields with the goal of economic development has the potential to lead to gentrification of areas adjacent to brownfields (Essoka 2010).

Gentrification entails several changes in the urban environment, such as housing price increases, demographic changes, and socio-economic changes (Benzhaf and McCormick 2007). There are few empirical papers that have looked at even two of these features simultaneously. There are numerous studies examining the economic and real-estate benefits of brownfield redevelopment (Longo & Alberini 2006; Boyle & Kiel 2001), but there is minimal research into the resulting socio-economic conditions of neighborhoods receiving EPA Pilot Grants. Table 2 provides a summary of three empirical studies that attempted to find the relationship between improving the environmental conditions associated with contaminated sites and gentrification. Eckerd (2010) did not find substantial evidence to support the claim that the cleanup of hazardous waste sites leads to gentrification. Pearsall (2010) also concluded that there is not significant data to claim brownfield redevelopment leads to gentrification. However Essoka (2010) provided evidence to support the hypothesis that redevelopment of brownfields leads to gentrification. The conflicting results of recent studies suggest that there is a need for further empirical studies into the spatial relationship between brownfield redevelopment and gentrification.

Table 2: Empirical studies of environmental improvement and gentrification

Article	Research Topic	Variables	Methodology	Results
Eckerd 2010 Time Frame: 1990-2000 Unit of Analysis: Block Group	LULUs and Environmental Gentrification in Portland, OR	Percentage of adult population with college education and % of adult population working in managerial and professional positions.	Used GIS to collect data, Gentrification Index: Ratio representing change between 1990 and 2000 for the two variables.	Found little evidence to support claim that cleanup of hazardous waste sites leads to gentrification.
Essoka 2010 Time Frame: 1990-2000 Unit of Analysis: Block Group	Brownfields and Gentrification in EPA Regions 3,4,6,9	Demographic variables: elderly, Black, White, Latino, and single mother with children.	Pretest-posttest comparison using 1990 and 2000 census. Compared test sites (0.5, 1, 1.5 mile radius around brownfield) to Metropolitan Areas using T-tests. Used GIS to create buffers and collect data.	Gentrification is often a consequence of brownfields redevelopment
Pearsall 2010 Time Frame: 1990-2000 Unit of Analysis: Block Group	Brownfields and Gentrification in NYC	Median property value, median household income, median gross rent, minority population, and residents over age of 65	Using 1990 and 2000 census, compared 36 redeveloped brownfields to 36 contaminated brownfields. Test site was 500 meter buffer around brownfield. Used GIS to create buffers and collect block group data	Half of the redeveloped brownfields experienced gentrification

Additionally, the studies shown in Table 2 were completed using the 2000 Census for examining the resulting conditions, leaving only approximately 5 years for the analysis of socio-economic change relative to a brownfield area being fully redeveloped. Consequently,

the opportunity is ripe for research into the post socio-economic conditions of brownfield redevelopments using up-to-date census data. This has the potential to reveal substantive conclusions on how brownfield redevelopment has impacted neighborhoods approximately 10-15 years after receiving EPA funding. In a survey of over 150 cities that were active in brownfields redevelopment, the average time to redevelop a brownfield site was five years (U.S. Conference of Mayors 2008). Considering a large majority of the brownfield pilot grants were awarded after 1995, there is a potential to gain further knowledge by utilizing more recent census data to determine the long-term socio-economic outcomes of brownfield redevelopment.

CHAPTER 4: RESEARCH DESIGN

This chapter provides the methodology used to answer the three research questions stated in Chapter 1 (i.e., Is there a relationship between brownfield sites and environmental injustice?; Has the EPA Brownfield Pilot Program (EPA-BPP) resulted in gentrification of areas adjacent to former brownfields?; If gentrification has occurred, what is the spatial extent of the gentrification?). The methodology is divided into two phases. The first phase uses a cross-sectional approach, which examines the issue of environmental justice and its relationship to brownfields, posed in question one. The second phase uses a longitudinal approach in determining the relationship between brownfield redevelopment and gentrification (research questions two and three). Both approaches are explained in the first section of this chapter. The remaining sections of the chapter describe the data collected and the research methods used to complete both the cross-sectional and longitudinal analyses.

4.1 Cross-Sectional and Longitudinal Approaches

A cross-sectional study is based on observations of phenomena at a single point in time, while the longitudinal study involves analyzing data at different points in time (Babbie 2010). In this study, the cross-sectional analysis determines whether or not areas adjacent to brownfields exhibit a significantly different socio-economic composition when compared to the whole city where the brownfield is located. The hypothesis is that areas adjacent to brownfields will exhibit higher minority and lower income residents compared to the average of the city in which the brownfield located. In order to determine the relationship between brownfields and gentrification, it is necessary to establish a historical context of whether low-income and minority populations were disproportionally exposed to contamination that

characterizes brownfields. For this reason, the cross-sectional study will be performed prior to the longitudinal study.

The longitudinal analysis examines the socio-economic changes that occur over time in two types of communities that have brownfields. First, it examines communities that received funding from the EPA Brownfield Pilot Program (treatment group). It also examines communities where brownfields have not received funding or have not been assessed prior to 2008 (control group). A control group is used to enhance the validity of the results and to ensure that the changes observed in the treatment group are the result of the EPA intervention. Treatment and control groups are compared using time-lapse analysis to determine if the clean-up of brownfields is followed by gentrification. Additionally, the longitudinal analysis provides insight about the spatial extent of gentrification by investigating the change in socio-economic variables across three distance intervals. The hypothesis for the longitudinal study is that following the EPA intervention, the control and treatment groups will exhibit significant differences in the socio-economic character of areas near the brownfield. In other words, the treatment group, which experienced the EPA intervention, will exhibit socio-economic changes that characterize gentrification.

4.2 Study Area

The study area is EPA Region 7, which includes the states of Iowa, Kansas, Missouri and Nebraska. Region 7 was selected as the study area because it received 12 pilot grants ($2.4 million total, combining of $200,000 each) as part of the EPA-BPP (EPA 2009b) between the years of 1995 and 1999. This amount is only a small fraction of the total money funded (4%) as part of the pilot program and may be the reason only limited brownfield

research has been completed within Region 7. In addition, gentrification and environmental justice research has focused on areas other than EPA Region 7, most often it is areas with more diverse socio-economic communities (Maranville et al. 2009; Greenberg et al. 2000; Essoka 2010). Figure 2 displays the cities that were selected as part of the pilot program and that will represent the treatment group for the longitudinal study; brownfields that will represent the control group are also displayed. The cross-sectional study will also use the 12 cities that are included in the treatment group. There are three cities (Springfield, St. Louis, and Kansas City) that are included in both the treatment and control groups, but different brownfields are used for the treatment and control groups. Additionally, the brownfields are greater than three miles apart so block groups that are selected for the treatment brownfields will not be included in the analysis of the control brownfields.

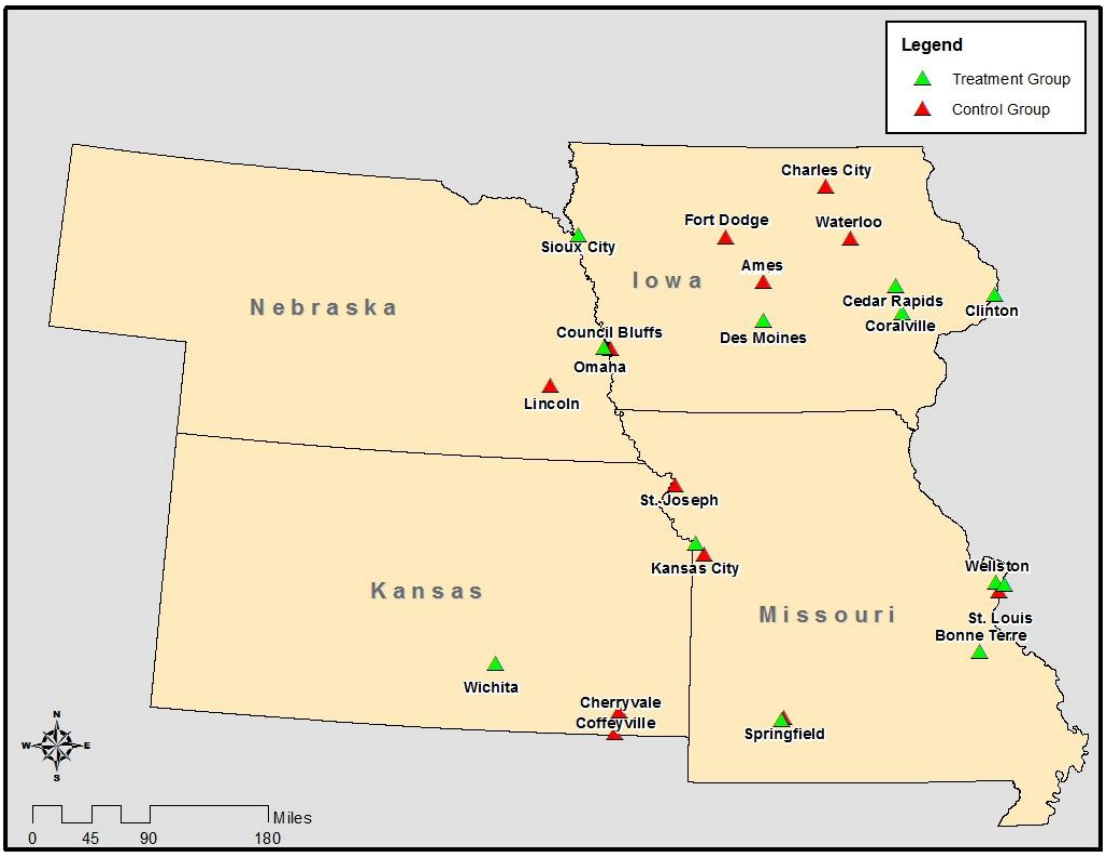

Figure 2: Treatment and control brownfields

Since the EPA does not keep record of brownfields that have not received EPA funding, the longitudinal study uses brownfields that received funding between 2008 and 2010 as the control group. It is assumed that these brownfields were contaminated sites prior to their designation as a brownfield. The 12 brownfields that will act as the control group and the 12 brownfields that will represent the treatment group for the longitudinal study are listed in Table 3. Also included in Table 3 is the address of the brownfield and whether or not the brownfields in the treatment group required clean up following the environmental assessment (EPA 2011).

Table 3: Treatment and control brownfield locations

Grant Recipient	Brownfield Location	Clean Up Required	Test Group
Bonne Terre, MO	2 School St W	Yes	Treatment
Cedar Rapids, IA	400 12th Avenue SE	Yes	Treatment
Clinton, IA	300 7th Ave	Yes	Treatment
Coralville, IA	222 & 228-232 1st Ave	Yes	Treatment
Des Moines, IA	100 Grand Ave E	No	Treatment
Kansas City, MO	Riverfront Drive	Yes	Treatment
Omaha, NE	1900 Capitol Ave	Yes	Treatment
Sioux City, IA	1201 Cunningham Drive	Yes	Treatment
Springfield, MO	2100 W. Catalpa	Yes	Treatment
St. Louis Co., MO (Wellston)	6600 Ridge Avenue	Yes	Treatment
St. Louis, MO	1st Street and Tyler Street	Yes	Treatment
Wichita, KS	N. Minnesota Street & E. 26th St.	No	Treatment
Ames, IA	806 Duff Avenue	-	Control
Charles City, IA	1200 2nd Street	-	Control
Cherryvale, KS	SW of Co. Roads 5190 and 5300	-	Control
Coffeyville, KS	1502 S Spruce Street	-	Control
Council Bluffs, IA	1103 6th Avenue	-	Control
Fort Dodge, IA	1st Avenue & S 12th Street	-	Control
Kansas City, MO	1711 Cherry Street	-	Control
Lincoln, NE	660 North Street	-	Control
Springfield, MO	710 E Phelps Street	-	Control
St. Joseph, MO	202 Main Street	-	Control
St. Louis, MO	4444 Gustine Avenue	-	Control
Waterloo, IA	1501 Sycamore Street	-	Control

The EPA-BPP grants are only intended to assist in assessment of contamination and planning for redevelopment. It is then up to the city or local government to find alternative funding for development and depending on the type of funding acquired, each city implemented different forms of redevelopment. Bonne Terre, MO redeveloped their former brownfield into commercial retail space. Cedar Rapids, IA created a green space along the Cedar River. Clinton, IA demolished a formerly contaminated building and left the property vacant. Coralville, IA redeveloped the brownfield into green space and Des Moines, IA

created a parking lot and park along the river front. Kansas City, MO constructed a casino and green space and Omaha, NE created a parking lot and renovated a low-rise residential building. Sioux city, IA demolished formerly contaminated buildings and the area is now an open green space along the Missouri River. Springfield, MO also demolished a formerly contaminated building and created open green space. The St. Louis, MO former brownfield is a vacant lot surrounded by industrial uses; similarly, the former brownfields located in Wellston, MO is now a vacant lot. Wichita, KS is the only city to redevelop a brownfield as a single family residential development, which is not surprising considering that it was one of the few brownfields in the treatment group that did not require cleanup (EPA 2009b).

It is important to highlight that there is a difference in the information provided for pilot grant awardees (treatment group) and recent brownfield grant recipients (control group). Unlike the detailed information provided for the treatment group, the EPA website (EPA 2011b) does not have exact latitude and longitude coordinates for the control group. Thus, state natural resource agencies were used for obtaining more precise information on the location of active brownfields and also the stage of assessment or cleanup of the brownfields (IDNR 2010; MDNR 2010; KDHE 2010; and NDEQ 2010). The EPA only provides general locations of recently awarded brownfields, but state agencies keep more detailed records of contaminated sites, such as more precise locations.

The spatial units of analysis within Region 7 are census block groups. Similar to previous studies of gentrification and environmental justice (Eckerd 2010; Maranville et al. 2009; and Essoka 2010), census block groups provide detailed information on the socio-economic composition of neighborhoods (Maranville et al. 2009). In addition, census block groups are used because they are the smallest unit of analysis of the American Community

Survey (ACS) 2009 5-year estimates and allow for a consistent method for analyzing change across three data sources (1990 Census, 2000 Census, and 2009 ACS). For the cross-sectional study, the area adjacent to the brownfield is defined as the census block groups that are within a 0.5 mile circular radius buffer (Essoka 2010). Other studies have defined a brownfield neighborhood as a 500 meter (0.3 mile) circular radius around a brownfield (Pearsall 2009). A slightly larger radius is used because a 0.5 mile buffer allows for a more general understanding of the socio-economic character of areas adjacent to brownfields.

The longitudinal study uses three circular radii distances around each brownfield (Figure 3). This provides an analysis of the spatial extent of socio-economic change that occurs in relationship with brownfield clean-up and redevelopment. The 0.5 mile circular radius determines the local effects, while the 1.0 mile and 1.5 mile radii help determine if clean-up and redevelopment of brownfields have larger socio-economic impacts.

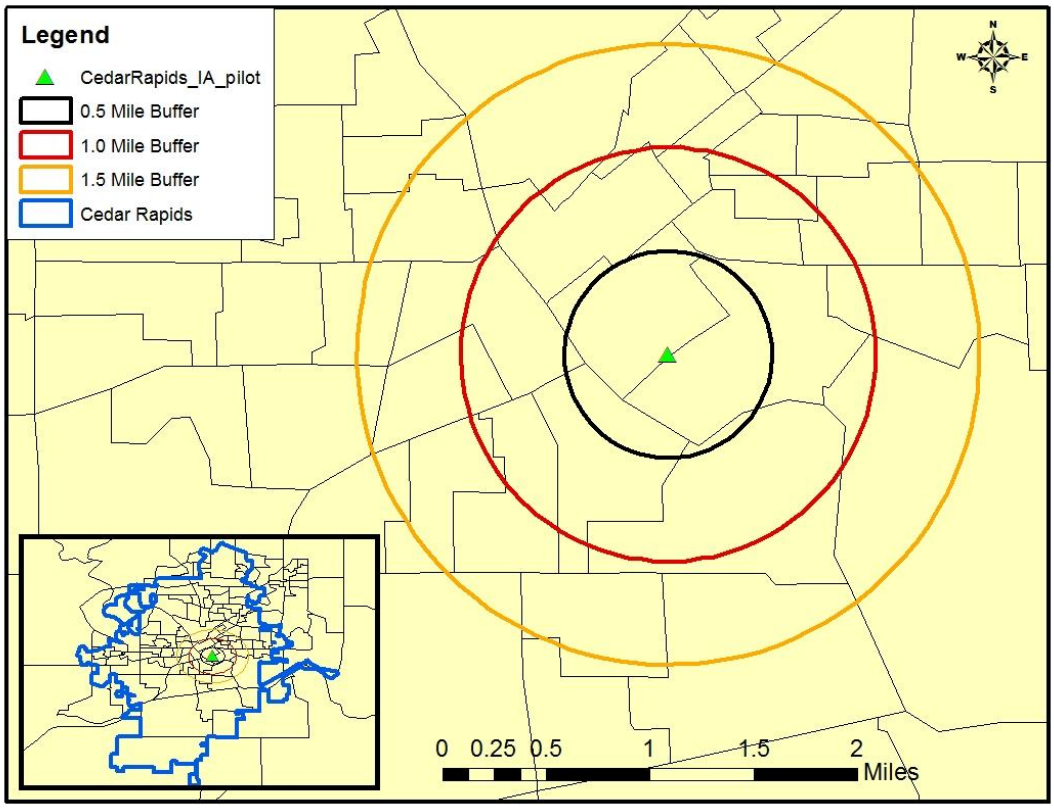

Figure 3: Three buffers used to determine spatial extent of gentrification

4.3 Data Sources

The cross-sectional analysis uses data from the 1990 Census. Three data sources are used as part of the longitudinal study: 1990 and 2000 Census and 2009 American Community Survey (ACS) 5-Year Estimates. 1990 Census data are used to determine the prior socio-economic conditions of areas adjacent to brownfields while the 2000 data are used as a measurable midpoint between the 19 year time span from 1990 to 2009. The ACS is a survey developed by the Census Bureau to replace the long form of the decennial census program (U.S. Census Bureau 2011). Unlike the decennial censuses, the ACS is a continuous national survey that collects data daily and summarizes it over 1-, 3-, and 5-year periods (U.S. Census Bureau 2009a). This study uses the 5-year estimates because it provides

demographic information for smaller geographic areas, such as census tracts and block groups. Survey methods include mailed questionnaires, telephone interviews, and visits from Census Bureau field representatives to about 3 million households (U.S. Census Bureau 2011). Similar to the decennial censuses, the ACS collects housing, economic, and social characteristics of the population. The advantage of the ACS is that it provides these data on a yearly basis which allows for continuous research of changing socio-economic variables (U.S. Census Bureau 2009a). The variables used in each analysis are discussed in next section.

4.4 Variables

The cross-sectional analysis is the first phase of this study because if brownfield neighborhoods are not socio-economically different than the cities, then there would be no reason to expect socio-economic changes that characterize the phenomena of gentrification (Pearsall 2010). Following the environmental justice research completed by Maranville et al. (2009), the 1990 census variables in the cross-sectional study are:

1) Percentage of population that is non-White
2) Homeownership (percent of housing units that are owner occupied housing units)
3) Median Household Income

These variables are compared between areas adjacent to brownfields (0.5 mile buffer) and the city that the brownfield is located in. The variables allow for an assessment of environmental justice and provide a picture of how areas adjacent to brownfields differ from their municipality in terms of race and ethnicity, socioeconomic status, and housing (Solitare and Greenberg 2002). Using the city of Cedar Rapids, IA as an example, Table 4 displays an

example of data gathered as part of the cross-sectional analysis. For the city of Cedar Rapids, only two census block groups were include in the 0.5 mile buffer and they are compared to 81 block groups that make up the City. This disparity in number of block groups is similar for the other pilot cities. Since the sample sizes are different for the 12 pilot cities, the two-sample t-test will assume unequal variance (further discussion of analytic method is provided in section 4.5.2). Additional descriptive statistics for each of the three variables of the cross-sectional analysis are provided in Appendix A, Tables 20, 21 and 22.

Table 4: Descriptive statistics for Cedar Rapids, IA

	% non-White		Median Household Income		% Owner Occupied Housing Units	
	0.5 Buffer	Cedar Rapids	0.5 Buffer	Cedar Rapids	0.5 Buffer	Cedar Rapids
Mean	24.1	4.0	9,038.5	31,864.2	33.5	66.5
Median	24.1	2.5	9,038.5	31,343.0	33.5	71.6
St. Deviation	4.2	5.5	2,605.7	10,716.3	14.3	23.7
Range	5.9	38.5	3,685.0	4,7622.0	20.2	97.1
Minimum	21.2	0.0	7,196.0	7,378.0	23.4	2.9
Maximum	27.1	38.5	10,881.0	55,000.0	43.6	100.0
Count	2.0	81.0	2.0	81.0	2.0	81.0

Graphical representations of the differences between the city average and brownfields area averages are shown Figures 4, 5, and 6. The three figures display the average values of each city and 0.5 mile buffer for each of the three variables measured from the 1990 Census. It can be observed in Figure 4 that the average percent non-White population was greater within the 0.5 mile buffer for all but three cities (Kansas City, MO; Bonne Terre, MO; Springfield, MO). Figure 5 shows that the average median household income was lower for the area adjacent to the brownfields in all but one city (Wellston, MO). The average percent

owner occupied housing units are displayed in Figure 6 and it is clear that the area near the brownfield was characterized by lower levels of owner occupied housing units.

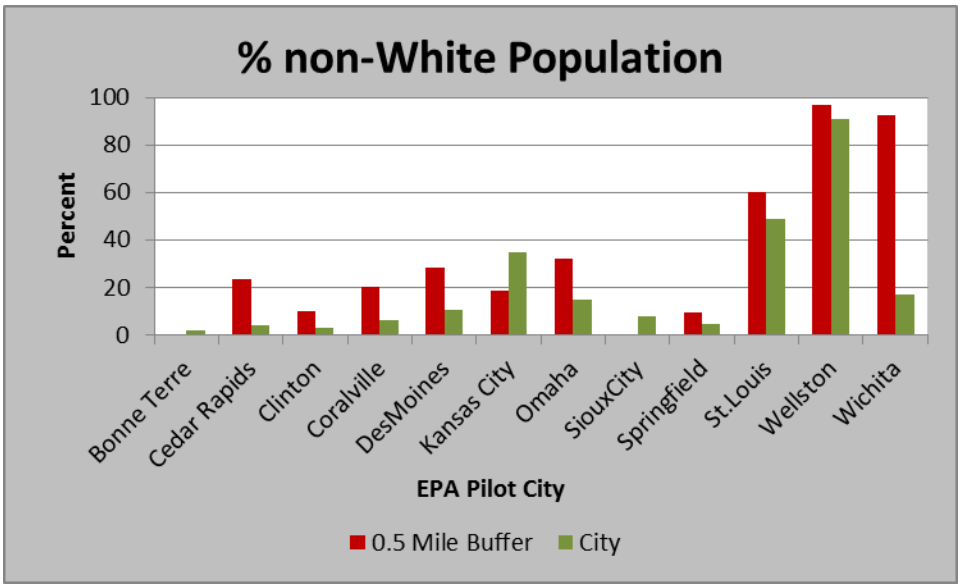

Figure 4: Average % non-White population for 0.5 mile buffers and cities

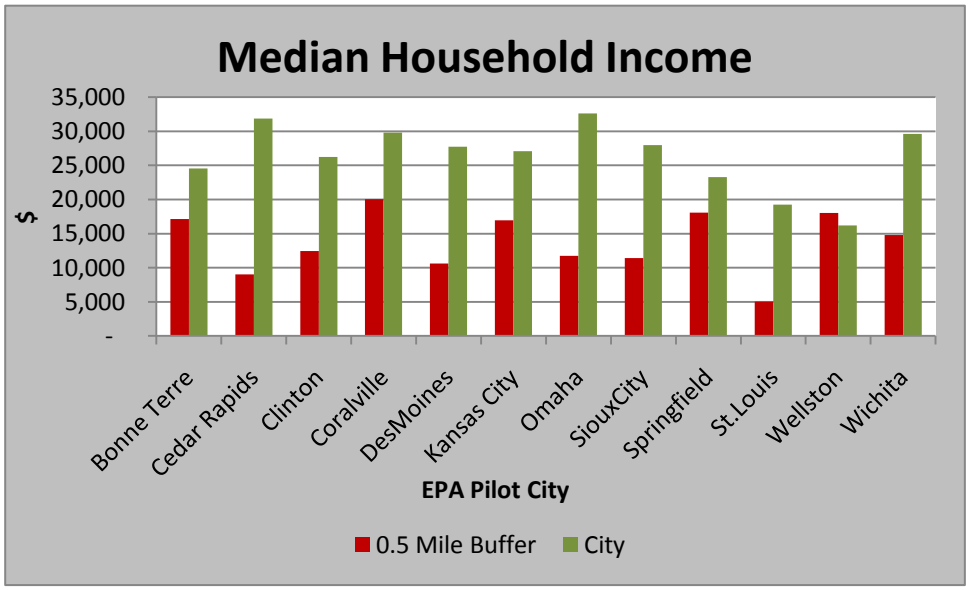

Figure 5: Average median household income for 0.5 mile buffers and cities

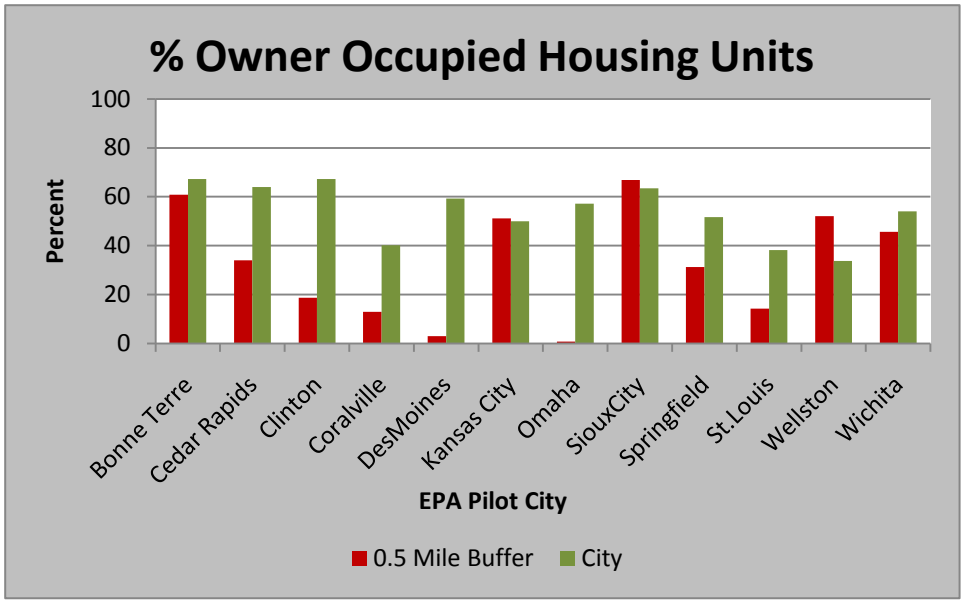

Figure 6: Average % owner occupied housing for 0.5 mile buffers and cities

The second phase of the study is the longitudinal analysis which tracks the socio-economic changes as the redevelopment occurs in areas surrounding brownfields; in addition to providing an analysis for the spatial extent of socio-economic change. The variables used to assess gentrification are organized into four categories: Housing Value, Occupancy Status, Socio-Economic Status, and Population. The four categories are based upon the three hallmarks of gentrification as explained by Benzhaf and McCormick (2007). The three hallmarks are: (1) rising property values and rental costs; (2) new construction or renovation upgrading the housing stock and perhaps converting it from rental to owner-occupied units; and (3) a turnover in the local population, bringing in residents with a higher socio-economic status (Benzhaf and McCormick 2007). The three hallmarks of gentrification can be thought of as indicators for the occurrence of class transformation and the investigation of variables that characterize the three hallmarks will determine if gentrification has happened.

The first hallmark will be expressed by the Housing Value category and includes census variables that measure cost of rent and value of housing units. The second hallmark, represented by Occupancy Status, includes measures of owner occupied and renter occupied housing units and also total housing units. The last hallmark is divided into two categories, Socio-Economic and Population. The Socio-Economic category consists of measures for household income and educational attainment. The Population category will consist of measures for total population and percent non-White. Table 5 displays census variables that represent the four categories used to evaluate gentrification.

Table 5: Variables used in longitudinal study to assess gentrification

Housing Value	Occupancy Status	Socio-Economic	Population
Median Gross Rent	Housing Units	Median Household Income	Total Population
Median Value for all Owner Occupied Housing Units	Percent of owner occupied housing units	Population with Bachelor's degree or higher (Educational Attainment)	Race (% non-White)
	Percent of renter occupied housing units	Households w/ Public Assistance Income (percent of total households)	

Descriptive statistics for each of the variables presented in Table 5 are available in Appendix B, Table 23. The descriptive statistics are shown for each variable for years 1990, 2000, and 2009; and also for each buffer (0.5, 1.0, and 1.5 mile). In addition, graphical representations of the trends observed for each variable are shown in Appendix C, Figures 11-20. Each figure displays the average change observed from 1990-2000, 2000-2009, and 1990-2009 for each of the buffer distances.

4.5 Methodology

This section presents the spatial procedures describing how a geographic information system (GIS) is used to organize and collect the data. In addition, it introduces the analytical method, which includes the t-test to be used in the cross-sectional phase and multivariate analysis of covariance (MANCOVA) to be used in the longitudinal phase of this study.

4.5.1 Spatial Procedures

The first step is to use ArcGIS to create a base map of EPA region 7 using the census boundary line block group files (U.S. Census Bureau 2009b). Two sets of boundary line files are used: 1990 block group boundaries and 2000 block group boundaries. The 2000 block group boundaries are used for both 2000 census data and 2009 ACS 5-year estimates data, since the 2009 data is based on the 2000 census boundaries (U.S. Census Bureau 2011). Block groups can be defined as geographic units that are created by the Census Bureau in partnership with local partners (city administrators). Block groups are created to approximate the geographic boundaries of neighborhoods (U.S. Census Bureau 2011). The next step in mapping the necessary spatial data is to input the latitude and longitude coordinates for the brownfields that make up the treatment and control groups. Each brownfields is represented by a point, rather than a more accurate representation such as a polygon. A point shapefile is used because there is inadequate data available for each brownfield to accurately create a polygon that fits the size and shape of the brownfield. The EPA database (EPA 2011) is not consistent in indicating the size and shape of brownfields.

Following the mapping of the aforementioned boundaries, census data from 1990, 2000, and 2009 are joined to the census block group boundary files. After the raw census

data has been joined to the census block group boundaries, the next step is to select block groups for the cross-sectional and longitudinal phases of this research.

Starting with the cross-sectional analysis, a 0.5 mile circular buffer is created around each brownfield that is listed as part of the treatment group in Table 3. This 0.5 buffer acts as the spatial boundary for the area adjacent to the brownfields. Those census block groups that have their centroids within the 0.5 mile buffer are selected to represent the brownfield neighborhood and act as the test group for the cross-sectional study. The centroid is the geometric center of a polygon, which in this case is each individual census block group (ESRI 2010). In the same way, census block groups with their centroids within the city boundary are selected and will be compared to the census block groups within the 0.5 mile buffer (Figure 7).

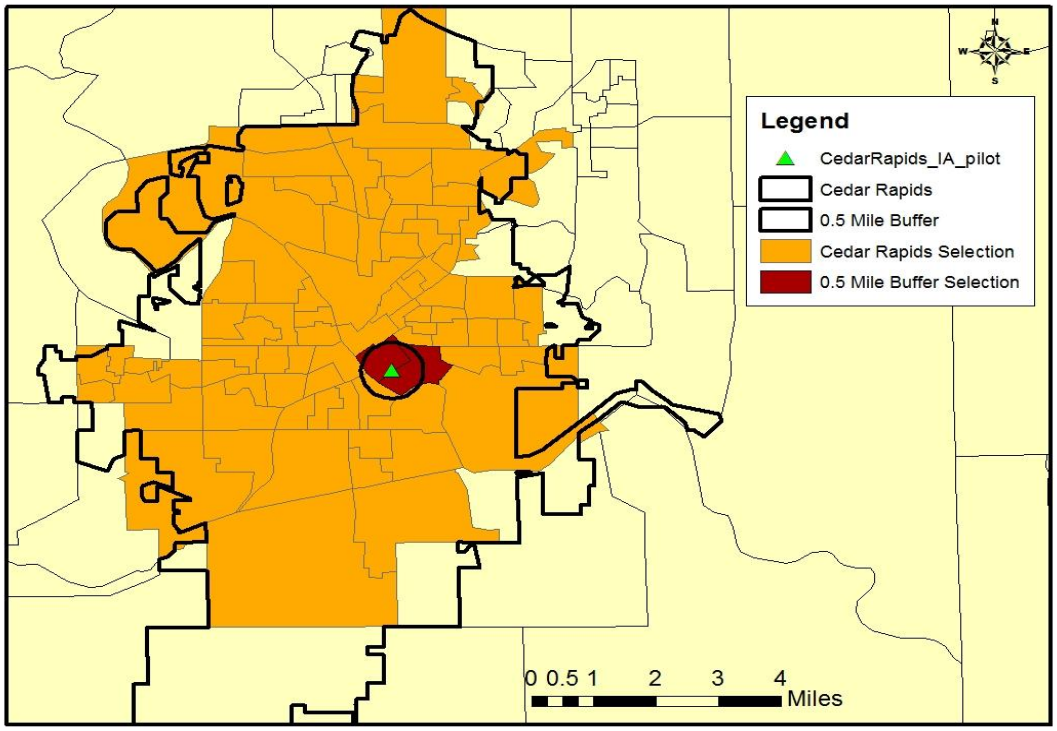

Figure 7: Selection of block groups for the cross-sectional study with Cedar Rapids as an example

For the longitudinal approach there is a need to expand on the number of buffers created. For each of the 12 pilot brownfields and the 12 control sites, three buffers (0.5, 1.0, and 1.5 mile) are created around each site. The three distance intervals will assess the spatial extent of gentrification (Essoka 2010). Selection of census block groups is based on whether the centroid of the block group polygon is within each of the three buffers.

To ensure that the spatial extent of gentrification is properly assessed, census block groups that fall within the 0.5 mile buffer will not be included as part of the 1.0 and 1.5 mile buffers. For the 1.0 mile buffer, representative block groups will only be those block groups that have their centroids within the 1.0 mile buffer but not those already selected in the 0.5 mile buffer. Similarly, for the 1.5 mile buffer analysis only those census block groups with their centroids within the 1.5 mile buffer, excluding the block groups that have already been selected in the 0.5 and 1.0 mile buffers will be selected (Figure 8).

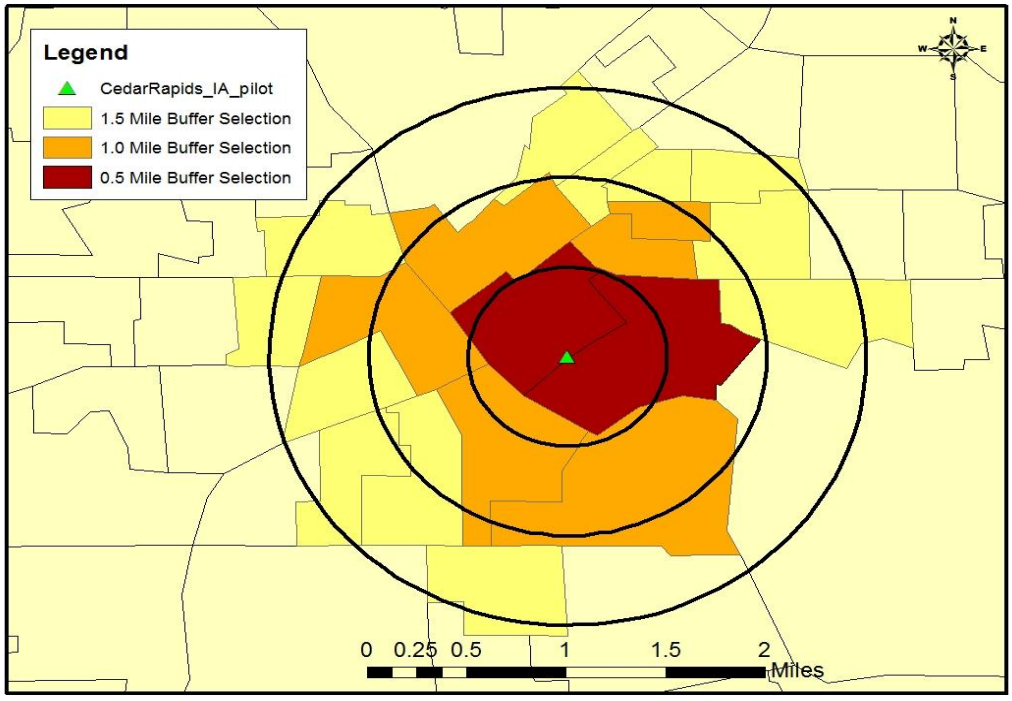

Figure 8: Longitudinal study and selection of block groups

4.5.2 Analytical Method: Cross-Sectional Analysis

The cross-sectional analysis uses two sample t-tests (assuming unequal variance) to determine if the brownfield area is significantly different than the city in which the brownfield is located. Given that the sample size for the number of block groups within the 0.5 mile buffer will be much less than the sample size of the city, the two-sample t-test will assume unequal variance. The t-test will provide evidence for whether there is environmental justice issues associated with brownfields. The two sample t-test is a statistical procedure that is used to determine if the mean difference between the two samples is significant (Lani 2009). For this study, the mean value for the area adjacent to the brownfield is compared to the mean of the city. For example, when compared to the city, if the brownfield area is composed of significantly higher minority population, lower home ownership rate, and/or lower household income, then there is evidence to support environmental injustice.

The procedure for a two sample t-test begins with posing hypotheses for the analysis. For this particular study, there are one null and one alternative hypothesis. The null hypothesis is: there is no significant difference between the city mean and the mean of the area adjacent to the brownfield (in reference to each of the three variables). The alternative hypothesis is that there is a significant difference between the city mean and the mean of the area adjacent to the brownfield. The significant difference can occur in two ways: (1) the particular variable city mean is greater for the area adjacent to the brownfield; or (2) the particular variable city mean is less for the area adjacent to the brownfield. If the data support alternative hypothesis (1) for minority population, then there is evidence for environmental injustice. If the data support alternative hypothesis (2) for owner occupied

housing units and median household income then there is also evidence for environmental injustice.

The formula for a two-sample t-test assuming unequal variance (Figure 9) is a ratio with the numerator representing the difference between the two means and the denominator representing the variance adjustment between the two means (Lani 2009).

$$T = \frac{\overline{X} - \overline{Y}}{\sqrt{\frac{S_X^2}{n_1} + \frac{S_Y^2}{n_2}}}$$

Figure 9: Two-sample t-test equation

Once the t-value is computed for each of the three measures of environmental justice, the value is measured against a significance value which is provided in a standard table of significance (t-table). The significance value is determined by the alpha level (p=0.05) and degrees of freedom. For this study, since the alternative hypothesis is that the two means are not equal and the resulting t-value can be positive or negative, a two-tailed test will be used. The alternative hypothesis is accepted if the calculated t-value is greater than the critical t value ($t_{0.05}$). The calculated t-value will be positive if the first mean (brownfield neighborhood) is larger than the second (city) and negative if it is smaller (Lani 2009).

4.5.3 Analytical Method: Longitudinal Analysis

The longitudinal analysis utilizes multivariate analysis of covariance (MANCOVA) to determine if gentrification has taken place near former brownfields. In addition, MANCOVA is also used to determine the spatial extent of gentrification. MANCOVA is appropriate for answering research questions (2) Has the EPA Brownfield Pilot Program resulted in gentrification of areas adjacent to former brownfields; and (3) If gentrification has occurred, what is the spatial extent of the gentrification?

The independent variable (IV) used in MANCOVA is whether a brownfield has received funding as part of the EPA Brownfield Pilot Program. The independent variable consists of two groups (12 cities in each group). One group, the treatment group, consists of brownfields that were chosen prior to 1999 to receive pilot grant funding. The other group, control group, consists of brownfields that have not received funding as of 2008. There are nine dependent variables (DV) and one covariate (CV). The nine DVs are displayed in Table 4. Since three of the DVs are monetary estimates (Median Gross Rent, Median Housing Value, and Median Household Income) and the study looks at three points in time, inflation must be accounted for. Based on the consumer price index for the Midwest urban region, 1990 and 2000 values were re-calculated to represent 2009 values (Bureau of Labor Statistics 2010). The CV is total population and it is used to control for differences in population observed at the 24 brownfield sites and ultimately reducing potential error in the model. The MANCOVA used for this analysis is composed of five steps (Minum et al. 1993):

1) Test ex ante assumptions
2) Interpret Omnibus Statistical Tests
3) Interpret Univariate Statistical Tests
4) Interpret Multiple Comparison Procedures (MCP)
5) Test ex post assumptions

The ex ante assumptions are tested to ensure the data exhibits characteristics that make it adequate for MANCOVA and tests of significance. The assumptions are as follows:

- Dependent variables (DV) and covariates (CV) are interval-ratio and independent variables (IV) are categorical

- Adequate sample size (N), general rule is N > p*k, with p= # of DVs and k= # of IV levels.
- DVs are normally distributed (skewness and kurtosis < +-2)
- No outliers (z-score +- 3-4 is outlier)
- Low correlations between CVs and IVs (Pearson's correlation < 0.7)

Following the interpretation of the data for the longitudinal study, it can be determined if each of the ex ante assumptions are satisfied. The assumptions and results from interpreting the data explicit to each assumption are bulleted below:

- *Dependent variables (DV) and control variables (CV) are interval-ratio and independent variables (IV) are categorical*. The 9 DVs and CV are interval-ratio. Each of the DVs and CV are measurements where the differences between two values are meaningful and each variable has a clear definition of zero. The IVs are categorical in that the brownfields are broken down into two categories: '1' is given to the 12 brownfields that received EPA-BPP funding and '2' is given to the 12 brownfields that did not receive pilot funding.
- *Adequate sample size (N), general rule is N > p*k, with p= # of DVs and k= # of IV levels.* The sample size for this study is 24, 12 pilot brownfields and 12 brownfields that did not receive pilot funding. The number of DVs is 9 and number of IV levels is 2. This provides that N(24) > p(9)*k(2). The assumption of adequate samples size is satisfied.
- *DVs are normally distributed (skewness and kurtosis < +-2).* DVs that are not normally distributed (Table 6) are transformed using log transformation.

Table 6: List of DVs that were not normally distributed

Transformed Variables		
1990	**2000**	**2009**
Population_0.5 Buffer	Population_0.5 Buffer	Population_0.5 Buffer
Population_1.0 Buffer	Population_1.0 Buffer	Population_1.0 Buffer
Population_1.5 Buffer	Population_1.5 Buffer	Population_1.5 Buffer
% non-White_0.5 Buffer	Edu. Attainment_1.0 Buffer	Edu. Attainment_1.5 Buffer
% non-White_1.0 Buffer	Edu. Attainment_1.5 Buffer	Median HH Inc._1.0 Buffer
% non-White_1.5 Buffer	Median HH Inc._1.0 Buffer	Median HH Inc._1.5 Buffer
Edu. Attainment_0.5 Buffer	HH w/ Pub. Assist. Inc._1.0 Buffer	Housing Units_0.5 Buffer
Edu. Attainment_1.0 Buffer	Housing Units_0.5 Buffer	Housing Units_1.0 Buffer
Edu. Attainment_1.5 Buffer	Housing Units_1.0 Buffer	Housing Units_1.5 Buffer
Median HH Inc._1.0 Buffer	Housing Units_1.5 Buffer	Gross Rent_1.0 Buffer
HH w/ Pub. Assist.Inc. _0.5 Buffer	Median HH Value_1.0 Buffer	Gross Rent_1.5 Buffer
Housing Units_0.5 Buffer	Median HH Value_1.5 Buffer	
Housing Units_1.0 Buffer		
Housing Units_1.5 Buffer		
Gross Rent_1.0 Buffer		
Median HH Value_1.0 Buffer		
Median HH Value_1.5 Buffer		

*Edu. = Educational, HH = Household, Inc. = Income, Pub. = Public, Assist = Assistance

- *No outliers (z-score +- 3-4 is outlier).* Histograms of each DV are provided upon request, histograms show the z-scores for the DVs and values that exceed +- 3-4 are outliers. Outliers were observed in many of the DVs, but given that the sample size is relatively small (N=24), the outliers were included in the analysis. Additionally, MCP tests are robust against outliers and the presences of extreme values are not anticipated to affect results.
- *Low correlations between CVs and IVs (Pearson's correlation < 0.7).* The results of the Pearson's r correlation tests are displayed in Table 7. Given that each of the CVs has a Pearson's r less than 0.7, it can be determined that there are low correlations between the CVs and IVs.

Table 7: Tests of correlation (Pearson's Coefficient) between IV and CVs

Pearson's r Correlation				
		0.5 Mi. Buffer	**1.0 Mi. Buffer**	**1.5 Mi. Buffer**
		POPULATION_09	POPULATION_09	POPULATION_09
IV	Pearson's r	.375	.197	-.050
		POPULATION_00	POPULATION_00	POPULATION_00
IV	Pearson's r	.320	.187	-.106
		POPULATION_90	POPULATION_90	POPULATION_90
IV	Pearson's r	.232	.133	-.093
		POPULATION_90-00	POPULATION_90-00	POPULATION_90-00
IV	Pearson's r	.380	.281	-.038
		POPULATION_00-09	POPULATION_00-09	POPULATION_00-09
IV	Pearson's r	.328	.135	.121
		POPULATION_90-09	POPULATION_90-09	POPULATION_90-09
IV	Pearson's r	0.51	.293	.103

In summary, the four ex ante assumptions of MANCOVA are satisfied and the analysis proceeds to the next step of MANCOVA. The next step involves interpreting Wilks' Lambda and Pillai-Bartlett tests to find significant difference between the treatment and control groups.

The omnibus statistical tests include an analysis of the Wilks' Lambda and Pillai-Bartlett Tests. Both tests provide evidence for either accepting or rejecting the null hypothesis which states that for all DVs the two levels of IV have the same mean. Lower values are better for the Wilks' Lambda and larger values are better for the Pillai-Bartlett statistic. If both the Wilks' Lambda and Pallai-Bartlett statistics are significant ($p < 0.05$) then the MANCOVA analysis can proceed to the evaluation of univariate tests. The results of the Wilks' Lambda and Pallai-Bartlett tests are detailed in chapter 5. For this study, it is expected that the DVs representing 1990 data will not be different between the two IVs since the EPA intervention did not take place until after 1993. Although, it is expected that the

DVs representing 2000 and 2009 data will be different between the two IVs and the two omnibus tests are expected to be significant.

The interpretation of univariate statistical tests involves the evaluation of analysis of variance (ANOVA). The ANOVA tests the model sum of squares (SS) for mean differences between DVs across levels of the IVs controlling for population (use CV). If the model SS is significant (less than 0.05) is provides evidence to reject the null hypothesis that the two levels of the IV have the same mean on a single DV when taking into account the CV. In addition, if the model SS is significant, then the next step in MANCOVA is to perform multiple comparison procedures (MCP). As before, the results of ANOVA are presented in chapter 5.

The interpretation of MCP requires the calculation of lease squares means. Least squares are predicted population marginal means while controlling for CV effects. One of two tests (LSD or Bonferroni) can be used in completing MCP. LSD is the more liberal of the two while the Bonferroni is often used in statistical tests because it is a good middle ground between the liberal and conservative tests. For this study, the Bonferroni model is used to measure the least squares mean difference. The hypotheses for the 9 DVs across the three time periods and for the three buffer distances are displayed in Table 8.

The hypotheses are based on the three hallmarks of gentrification described by Banzhaf and McCormick 2007. It is expected that following redevelopment of brownfields, the area will see a decrease in the non-white population, an increase in the level of educational attainment of residents, decrease in households with public assistance income, increase in median household income, increase in housing units, increase in owner occupied housing units, decrease in renter occupied housing units, increase in gross rent, and increase

in median value for owner occupied housing units. The greatest difference is expected to occur within the 0.5 mile buffer, with significant differences decreasing in the 1.0 and 1.5 mile buffers.

Table 8: Hypotheses for MANCOVA statistical tests

Difference of the Treatment from Control						
				Change From:		
	1990	2000	2009	90-00	00-09	90-09
Percent non-White	=	-	-	-	-	-
Educational Attainment	=	+	+	+	+	+
Households w/Pub. Assist Income	=	-	-	-	-	-
Median Household Income	=	+	+	+	+	+
Housing Units	=	+	+	+	+	+
Owner Occupied Housing Units	=	+	+	+	+	+
Renter Occupied Housing Units	=	-	-	-	-	-
Gross Rent	=	+	+	+	+	+
Median Household Value	=	+	+	+	+	+

The hypotheses presented in Table 8 represent what would be expected if gentrification followed investment in brownfield redevelopment. It is not to be expected that the treatment and control groups to be different in 1990 because neither groups has received EPA funding for clean-up. Differences between the two groups would be expected for the years 2000 and 2009. For example, the difference of the treatment from control group is hypothesized to be negative for percent non-White population in year 2000. This means that if the treatment group has a value of 25% and the control group has a value of 60%, then the resulting difference is -35% and the result is consistent with the hypothesized negative value. If this hypothetical example is significant, then the ex post assumptions are evaluated. to determine if the significant difference is the result of correlation or non-normal distribution.

The two ex post assumptions are evaluated to determine if the significant differences found in the MCP tests result in non-normal distribution of residuals and/or unequal variance. The two ex post assumptions are:

- Standardized residuals have a normal distribution (normal distribution shown in histogram)
- Homoscedasticity (Levene's test of equal variances)

Fulfillments of the ex post assumptions will provide further evidence that the differences exhibited between the control and treatment groups are indeed significant and not a result of errors in the model, such as unaccounted for DVs or CVs. The ex post assumptions will be evaluated for only those DVs that have statistically significant differences as indicated by the MCP tests. An analysis of the assumptions is provided in chapter 5.2.5 MANCOVA ex post Assumptions.

CHAPTER 5: RESULTS

This chapter will present the results obtained from the cross-sectional and longitudinal approaches. The cross-sectional study and results from the t-test is presented first, followed by the longitudinal study and results from MANCOVA.

5.1 Cross-Sectional Study Results

The cross-sectional study used two-sample t-tests to compare means of the area adjacent to the brownfield (census block groups within 0.5 mile buffer) and the city mean, in which the brownfield is located. The 1990 means of three variables were compared (only for the treatment group): non-White population, median household income, and percent of housing units that are owner occupied housing units. The results from the two-sample t-tests for each variable are presented below.

5.1.1 Non-White population

The results from the two-sample t-tests for non-White population are displayed in Table 9. For the area adjacent to brownfield, the average percent of non-White population (44 %) is greater than the average of the cities (43.4 %) which host the brownfields; but the difference is not found to be significant and suggesting that environmental justice is not an issue. Additional descriptive statistics of non-White population are provided for both the 0.5 mile buffer and city in Appendix A (Table 20). Even though combined samples means are not found to be significantly different, there are five areas in which the difference between the city and brownfield area are significantly different (Clinton, IA; Coralville, IA; Des Moines, IA; Sioux City, IA; and Wichita, KS).

Table 9: T-test results for % of non-White population

% non-White		
	0.5 Mile Buffer	City
Combined Sample Means	44.0	43.4
Bonne Terre, MO	0.0	29.3
Cedar Rapids, IA	24.1	4.0
Clinton, IA	81.5*	35.1
Coralville, IA	20.4*	6.7
Des Moines, IA	27.6*	11.0
Kansas City, MO	23.1	35.5
Omaha, NE	47.1	109.2
Sioux City, IA	0.0*	7.6
Springfield, MO	9.1	4.3
St. Louis Co., MO	97.4	90.1
St. Louis, MO	30.1	46.5
Wichita, KS	92.3*	18.0

*Significant difference of means at $p<0.05$

Although results of the two-sample t-test are not significant for combined sample means of percent non-White population, the results seem to show a trend of increased non-White population for the area adjacent to brownfields. After interpreting the results for percent non-White population, further evidence of environmental injustice is needed. Interpretation of results for the two remaining variables (Median Household Income and Owner Occupied Housing Units) will help to provide evidence for issues of environmental justice.

5.1.2 Median Household Income

The results of the two-sample t-tests for median household income are presented in Table 10. The average median household income for the cities which contain the brownfields is almost double the average median household income of the areas adjacent to brownfields and is found to be statistically significant. In addition, eight of the twelve pilot cities were

observed to have statistically significant differences in median household income for the area near the brownfield compared to the remainder of the city.

Table 10: T-test results for median household income

Median Household Income		
	0.5 Mile Buffer	City
Combined Sample Means	14,445*	26,731
Bonne Terre, MO	17,125	24,551
Cedar Rapids, IA	9,039*	31,864
Clinton, IA	12,445*	26,256
Coralville, IA	20,026	29,819
Des Moines, IA	10,638*	27,723
Kansas City, MO	16,966*	27,058
Omaha, NE	11,758*	32,593
Sioux City, IA	22,823*	27,958
Springfield, MO	18,083	23,271
St. Louis Co., MO (Wellston)	18,036	16,221
St. Louis, MO	5,030*	19,263
Wichita, KS	14,793*	29,614

*Significant difference of means at $p<0.05$

As displayed in Table 10, there is a statistically significant difference in median household income with the 0.5 mile buffer exhibiting lower levels of income. The significant results support the theory that environmental justice issues, specifically the abundance of lower income residents, are associated with contaminated brownfields.

5.1.3 Owner Occupied Housing Units

The results of the two-sample t-tests for percent of housing units that are owner occupied are presented in Table 11. For the areas adjacent to brownfields, the average percent of owner occupied housing is 30.2, this is significantly less than the average percent of owner occupied housing for the cities (54.3 %).

Table 11: T-test results for perecent owner occupied housing units

% Owner Occupied Housing Units		
	0.5 Mile Buffer	City
Combined Sample Means	30.2*	54.3
Bonne Terre, MO	60.2	69.4
Cedar Rapids, IA	33.5	66.5
Clinton, IA	20.7	67.5
Coralville, IA	12.9*	42.7
Des Moines, IA	3.3*	62.6
Kansas City, MO	51.1	53.5
Omaha, NE	0.9*	61.7
Sioux City, IA	34.0	65.4
Springfield, MO	31.9	52.2
St. Louis Co., MO (Wellston)	51.9*	36.6
St. Louis, MO	14.3*	40.2
Wichita, KS	45.7	56.8

*Significant difference of means at $p<0.05$

In summary, the significant results for owner occupied housing units, along with median household income, suggest that there are environmental justice issues for areas adjacent to brownfields. Although results for percent non-White population were not statistically significant, the results show a trend of higher non-white populations near brownfields. If low-income and minority residents are present near brownfields, as the cross-sectional analysis suggests, prior to receiving funding from the EPA-BPP then the longitudinal analysis will provide a method for determining if the disadvantaged population is replaced by more affluent residents through the process of gentrification.

5.2 Longitudinal Study Results

The results from the longitudinal study are presented below. Organization of the results follow the organization of the MANCOVA test as described in chapter 4 Research Design.

5.2.1 MANCOVA Omnibus Test Results

The purpose of interpreting the omnibus statistical tests, specifically Wilks' Lambda and Pillai-Bartlett tests, are to determine if there is a mean difference between the two groups of IVs for all DVs. The results of the two tests are displayed in Table 12. The value given in the table is the value of each test statistic and values with an asterisk are significant ($p<0.05$). The table represents all DVs for the particular year and distance interval. The results show that there is a significant difference between the treatment and control group for the year 2000 and within the 0.5 mile buffer. In addition, the observed change between 2000 and 2009 was found to be significant for both the 0.5 mile and 1.0 mile buffers.

Table 12: Results from omnibus tests, including Pillai-Bartlett and Wilks' Lambda.

		Wilks' λ	Pillai-Bartlett
0.5 Mile			
	1990	0.64	0.36
	2000	0.23*	0.77*
	2009	0.43	0.57
	90-00	0.46	0.54
Change From	00-09	0.24*	0.76*
	90-09	0.52	0.48
1.0 Mile			
	1990	0.45	0.55
	2000	0.46	0.54
	2009	0.47	0.53
	90-00	0.70	0.30
Change From	00-09	0.28*	0.72*
	90-09	0.55	0.45
1.5 Mile			
	1990	0.54	0.46
	2000	0.46	0.54
	2009	0.45	0.55
	90-00	0.40	0.60
Change From	00-09	0.51	0.49
	90-09	0.61	0.39

*Significant difference between treatment and control group at $p<0.05$

Given the significant difference between the treatment and control groups, the next step is to interpret the univariate tests. The univariate tests determine which DVs show differences in means between the treatment and control groups.

5.2.3 MANCOVA Univariate Test Results

The univariate test involves interpreting the F values for each DV across the two levels of IV. The null hypothesis for the univariate tests states that there are no differences on the DVs across levels of the IV (treatment and control) controlling for CV. The DVs and their calculated F values are presented in three tables with each table representing one of three buffer distance (Table 13, 14 and 15). The DVs that show significant differences ($p<0.05$) across the two levels of IV controlling for CV indicates there is potential to see significant results for these variables in the MCP tests.

Table 13: Univariate Test Results for 0.5 mile buffer

Univariate Test: F Values						
				Change From:		
	1990	2000	2009	90-00	00-09	90-09
non-White	2.19	3.95*	2.31	0.10	0.54	1.22
Educational Attainment	0.34	0.65	0.24	0.11	3.42	1.45
Households w/Pub. Assist Income	1.82	1.59	0.23	1.04	0.06	1.30
Median Household Income	0.34	0.39	1.32	0.47	3.33	2.77
Housing Units	87.17*	30.56*	28.23*	3.76*	1.82	6.47*
Owner Occupied Housing Units	0.32	0.38	0.09	0.13	0.15	0.19
Renter Occupied Housing Units	0.25	0.27	0.07	1.73	3.07	0.17
Gross Rent	0.03	2.21	0.82	2.18	0.44	2.03
Median Household Value	1.10	0.56	4.37*	0.48	0.42	0.43

*Significant at $p<0.05$

Table 13 displays the results from the 0.5 mile buffer and shows that there is a mean difference between the treatment and control group for non-White population, housing units, and median household value. Differences in total housing units was observed at all three

points in time, while non-White population was significant at year 2000 and median household value was significant at year 2009. The results of the univariate tests merely indicate that the aforementioned DVs have mean differences across the two levels of IVs, but not the direction of change. Determination of whether values of DVs increased or decreased and whether or not the difference between the treatment and control groups is significant is left to the MCP tests.

Table 14: Univariate Test Results for 1.0 mile buffer

Univariate Test: F Values						
				Change From:		
	1990	2000	2009	90-00	00-09	90-09
non-White	3.51*	3.46*	2.71	0.70	0.90	1.83
Educational Attainment	0.59	0.73	0.01	0.52	0.47	0.07
Households w/Pub. Assist Income	1.57	3.56*	1.20	3.94*	0.69	2.23
Median Household Income	0.23	0.46	0.16	0.98	0.43	0.64
Housing Units	329.41*	124.53*	570.55*	1.20	1.05	12.69*
Owner Occupied Housing Units	2.10	3.19	1.51	0.05	1.10	0.50
Renter Occupied Housing Units	1.82	2.44	1.87	1.21	0.10	0.07
Gross Rent	0.02	0.02	0.35	0.32	0.83	0.03
Median Household Value	0.10	0.41	0.46	3.54*	2.37	2.24

*Significant at $p<0.05$

Results of the 1.0 mile buffer (Table 14) are similar to the 0.5 mile buffer. There is an observed difference between the treatment and control groups for housing units, percent non-White population, and median household value. The 1.0 mile buffer is different from the 0.5 mile buffer in that households with public assistance income is significantly different between the two levels of IV at years 2000 and change from 1990-2000. The difference in households with public assistance income will be further explored in the MCP tests.

Table 15: Univariate Test Results for 1.5 mile buffer

Univariate Test: F Values						
				Change From:		
	1990	2000	2009	90-00	00-09	90-09
non-White	7.83*	3.91*	4.21*	1.02	2.24	18.48*
Educational Attainment	0.10	0.52	0.17	2.44	0.10	1.05
Households w/Pub. Assist Income	2.28	1.52	3.38*	2.91	0.33	1.78
Median Household Income	0.52	2.36	0.21	1.47	0.72	0.69
Housing Units	189.59*	50.39*	240.83*	0.89	5.12*	21.81*
Owner Occupied Housing Units	4.05*	4.78*	2.37	0.11	0.65	0.34
Renter Occupied Housing Units	3.81*	5.47*	2.41	0.82	0.26	0.15
Gross Rent	0.01	0.28	1.37	2.66	1.68	0.60
Median Household Value	0.25	0.05	0.29	1.51	1.22	0.18

*Significant at $p<0.05$

The univariate test results for the 1.5 mile buffer (Table 15) shows similar differences of DVs as seen in the 0.5 and 1.0 mile buffers. Similar to the two previous buffer distances, there is a statistical difference between the two levels IV for percent non-White population, households with public assistance income and housing units. The 1.5 mile buffer differs from the two previous buffers in that owner occupied housing units and renter occupied housing units were significantly different between the treatment and control groups. The MCP tests will determine if the significant DVs of the Univariate Tests are statistically significant and if the direction of change provides evidence of gentrification.

5.2.4 MANCOVA Multiple Comparison Procedure Results

Results from the multiple comparisons procedure (MCP) are shown in Tables 16, 17, and 18. Table 16 shows the results for the 0.5 mile buffer, Table 17 provides results for the 1.0 mile buffer and Table 18 displays results for the 1.5 mile buffer.

The 0.5 mile buffer results indicate that the majority of the DVs do not show a statistically significant difference between the treatment and control groups. The three

variables that produced significant results are percent non-White for the year 2000, Educational Attainment for the change from 2000-2009 and Median Household Income for change from 2000-2009 and 1990-2009. In addition, most of the variables do not show results consistent with what is hypothesized to be the results if gentrification has occurred.

Table 16: Results from MCP tests for 0.5 mile buffer.

0.5 Mile Buffer: Difference of the Treatment from Control							
					Change From:		
		1990	2000	2009	90-00	00-09	90-09
% non-White	Hypothesis	=	-	-	-	-	-
	Results	0.37	26.08*	22.71	**-1.46**	**-1.74**	**-0.12**
Educational Attainment	Hypothesis	=	+	+	+	+	+
	Results	-0.14	-2.99	**1.40**	-0.39	**6.31***	**5.71**
Households w/Pub. Assist Inc	Hypothesis	=	-	-	-	-	-
	Results	4.84	2.71	1.05	**-5.80**	**-0.65**	**-1.33**
Median Household Income	Hypothesis	=	+	+	+	+	+
	Results	-2048	-2340	**6486**	**3270**	**6788***	**12441***
Housing Units	Hypothesis	=	+	+	+	+	+
	Results	-0.01	-0.03	**0.07**	-26.56	**77.99**	**59.09**
Owner Occupied Housing Units	Hypothesis	=	+	+	+	+	+
	Results	-4.89	-8.75	-3.84	**0.25**	-1.07	**0.72**
Renter Occupied Housing Units	Hypothesis	=	-	-	-	-	-
	Results	5.17	2.49	**-1.43**	**-7.58**	4.89	**-2.30**
Gross Rent	Hypothesis	=	+	+	+	+	+
	Results	-2.81	**84.92**	**107.24**	**90.08**	**38.70**	**187.45**
Median Household Value	Hypothesis	=	+	+	+	+	+
	Results	-1070	-257	**12241**	**7323**	**10524**	**12252**

BOLD values are consistent with hypothesis
*Results significant at p<0.05

The 1.0 mile buffer results (Table 17) was similar to the 0.5 mile buffer in that a majority of the DVs do not show a statistically significant difference between the treatment and control groups. The lone DV that showed significant difference was percent non-White population. The treatment group was significant larger for the years 2000 and 2009. Also, only a small number of DVs show results that are consistent with the hypothesized results

that one would expect if gentrification was taking place in areas near redeveloped brownfields.

Table 17: Results from MCP tests for 1.0 mile buffer

1.0 Mile Buffer: Difference of the Treatment from Control							
					Change From:		
		1990	2000	2009	90-00	00-09	90-09
% non-White	Hypothesis	=	-	-	-	-	-
	Results	0.38	24.91*	21.26*	1.02	**-2.96**	**-1.45**
Educational Attainment	Hypothesis	=	+	+	+	+	+
	Results	-0.04	-0.14	-0.02	-0.72	**1.54**	**0.65**
Households w/Pub. Assist Inc	Hypothesis	=	-	-	-	-	-
	Results	5.51	3.11	1.99	**-1.85**	**-1.26**	**-2.61**
Median Household Income	Hypothesis	=	+	+	+	+	+
	Results	0.00	-0.03	-0.03	-2312	**846**	-2251
Housing Units	Hypothesis	=	+	+	+	+	+
	Results	0.00	**0.07**	**0.03**	**590.54**	-458.85	**127.77**
Owner Occupied Housing Units	Hypothesis	=	+	+	+	+	+
	Results	-5.73	-7.80	-4.92	-0.36	**2.46**	**2.42**
Renter Occupied Housing Units	Hypothesis	=	-	-	-	-	-
	Results	3.08	4.32	3.67	0.76	0.16	0.39
Gross Rent	Hypothesis	=	+	+	+	+	+
	Results	0.00	**2.76**	0.00	**21.79**	-6.34	**6.48**
Median Household Value	Hypothesis	=	+	+	+	+	+
	Results	-0.01	**0.02**	**10569**	**18917**	**6942**	**19803**

BOLD values are consistent with hypothesis
*Results significant at p<0.05

Consistent with the previous buffers, the 1.5 mile buffer (Table 18) did not show significant results for most of the DVs. There are three DVs that display significant differences between the treatment and control groups; Educational Attainment for change from 1990-2000, Households with public assistance incomes for change from 1990-2000, and Housing Units for the year 2009. Similar to the previous 0.5 and 1.0 mile buffers, only a small number of DVs show results that follow the hypothesized results. It should also be

noted that two of the DVs that are significant (Educational Attainment and Housing Units), the results are not consistent with the hypothesized results.

Table 18: Results from MCP tests for 1.5 mile buffer

1.5 Mile Buffer: Difference of the Treatment from Control							
					Change From:		
		1990	2000	2009	90-00	00-09	90-09
% non-White	Hypothesis	=	-	-	-	-	-
	Results	0.36	14.02	16.90	**-4.34**	3.60	0.05
Educational Attainment	Hypothesis	=	+	+	+	+	+
	Results	0.01	-0.06	-0.03	-1.49*	-0.26	-1.72
Households w/Pub. Assist Inc	Hypothesis	=	-	-	-	-	-
	Results	3.98	0.72	0.38	**-3.02***	**-0.21**	**-2.91**
Median Household Income	Hypothesis	=	+	+	+	+	+
	Results	-587	**1254**	-0.01	655	-4182	-3301
Housing Units	Hypothesis	=	+	+	+	+	+
	Results	-0.06	**0.06**	-0.08*	969.08	-832.46	**71.94**
Owner Occupied Housing Units	Hypothesis	=	+	+	+	+	+
	Results	-7.07	-7.14	-5.28	-0.82	**2.39**	**1.22**
Renter Occupied Housing Units	Hypothesis	=	-	-	-	-	-
	Results	4.93	5.63	4.97	1.50	**-1.90**	**-0.01**
Gross Rent	Hypothesis	=	+	+	+	+	+
	Results	4.73	-30.76	**0.06**	-36.39	**93.69**	**52.85**
Median Household Value	Hypothesis	=	+	+	+	+	+
	Results	0.03	**0.02**	**11896**	-2665	**11618**	**7637**

BOLD values are consistent with hypothesis
*Results significant at p<0.05

Overall, the MCP tests do not show significant results indicating the process of gentrification has taken place. In fact, the results show that for the treatment brownfields, the number of housing units decreased from 1990-2009 for the 0.5 and 1.0 mile buffers (Appendix C, Figure 11). Accompanied with the decrease in housing units was also a decrease in owner occupied housing units and renter-occupied housing units. The decrease in number of housing units and owner-occupied housing is contrary to the second hallmark of gentrification which states that gentrification occurs when there is new construction of

housing stock and rental housing units are converted to owner occupied housing units (Benzhaf and McCormick 2007).

It is not surprising to see a decrease in housing units considering that only one city completed a brownfield redevelopment project that included the construction of new housing, which was Wichita, KS. The 11 remaining pilot cities did not include residential development on former brownfields, but instead, planned for development of land uses such as industrial, commercial, green space, agri-industrial and light industrial. The common trend of developing non-residential land use on former brownfields may explain the lack of growth in housing units within the 0.5 mile and 1.0 mile buffer of brownfields (EPA 2009a).

In addition to a decrease in housing units, total population was found to decrease following redevelopment. The decrease in housing units may explain for the observed decrease in total population for the treatment group. Treatment brownfield sites saw a decrease in population from 1990-2009 within all three buffer distances (Appendix C, Figure 12). The decrease in population could be expected if the redeveloped land use was green space or commercial rather than residential. Referring back to Smith's (1979) rent-gap theory, if the most profitable potential ground rent is a land use other than residential, then it would explain the decrease in housing units and the subsequent decrease in total population.

Although the total population was observed to decrease for the treatment brownfields, the percent of non-White population increased from 1990-2009 for all three buffer distances (Appendix C, Figure 13). While the treatment group saw an increase in non-White population, the control brownfields were seen to have an even greater increase in non-White population along with a decrease in median household income from 1990-2009 within the 0.5 mile buffer. The increase in non-White population and decrease in median household income

for the control brownfields suggest possible environmental justice issues. Tiebout's (1956) local public goods theory can explain the changes seen within the control brownfields. Since the control group represents contaminated brownfields with no investment from the EPA, the theory predicts that low-income and minority populations will sacrifice environmental quality for more affordable housing, and since brownfields negatively impact property values the low-income population will likely live near brownfields.

While median household income was seen to decrease for the control group, the treatment group observed an increase and the changes in income from 2000-2009 and 1990-2009 for the 0.5 mile buffer were statistically significant. Along with the significant increase in educational attainment from 200-2009 for the 0.5 mile buffer, and the decrease in households with public assistance income for the 1.5 mile buffer, there is evidence to support the third hallmark of gentrification (turnover in the local population, bringing in residents with a higher socio-economic status).

In summary, the MCP tests provide evidence to support the third hallmark of gentrification, which states that gentrification is characterized by a turnover in the socio-economic status of residents. However, the first and second hallmarks, which deal with decreasing minority population and increase in housing units, are not supported by the data. Not only does the data not support the first two hallmarks, but it actually shows trends that are opposite of what is expected. Housing units decreased, total population decreased, and the non-White population increased. The 11 DVs that are found to be significant will be tested to insure they fulfill the ex post assumptions of MANCOVA, discussed in the next section.

5.2.5 MANCOVA ex post Assumptions

The ex post assumptions will only be performed for those variables that showed significant differences between the treatment and control groups as a product of the MCP tests. The variables are:

- % non-White (0.5 mile buffer, year 2000)
- Educational Attainment (0.5 mile buffer, change from 2000-2009)
- Median Household Income (0.5 mile buffer, change from 2000-2009 and 1990-2009)
- % non-White (1.0 mile buffer, years 2000 and 2009)
- Educational Attainment (1.5 mile buffer, change from 1990-2000)
- Households with public assistance incomes (1.5 buffer, change from 1990-2000)
- Housing Units (1.5 mile buffer, year 2009).

Each of the three ex post assumptions will be addressed below:

1. *Standardized residuals have a normal distribution (normal distribution shown in histogram).* Histograms of the standardized residuals are presented in Appendix D. Of the nine DVs that were found to be significant in the MCP tests, only one does not show normal distribution of standardized residuals: Housing Units at the 1.5 mile buffer for year 2009. Figure 10 displays the histogram of Housing Units and it is evident that the distribution is positively skewed.

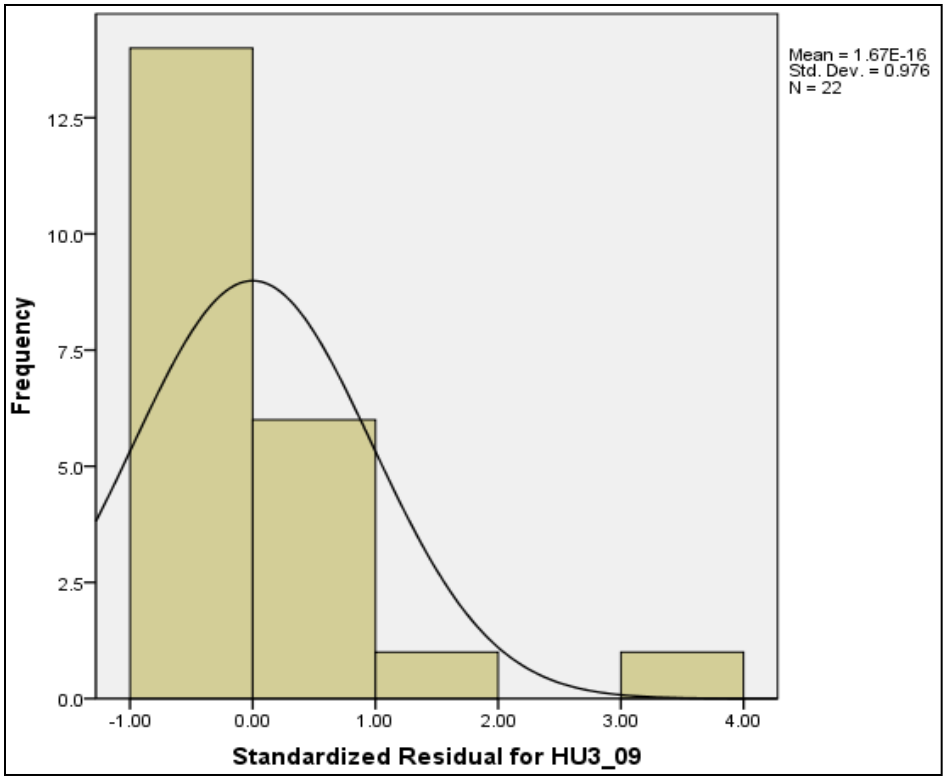

Figure 10: Distribution of standardized residuals for housing units (1.5 mile buffer and year 2009)

The non-normal distribution of Housing Units indicates that the MANCOVA model used in this analysis is missing an element that may better provide an estimate for the change in housing units.

2. *Homoscedasticity (Levene's test of equal variances).* The results from Levene's test are displayed in Table 19. The null hypothesis is that variance is equal across the two levels of IV. The goal is for the DVs to have non-significant results and to retain the null. The DV that did receive significant results was % non-White population. This DV was significant for the years 2000 (0.5 mile buffer and 1.0 mile buffer) and 2009 (1.0 mile buffer). The significance of the non-White population reveals that the error variances are not equal across the two levels of the IV and there are variables that are

unaccounted for in the MANCOCA model used in this study; variables that may better explain the change in percent non-White population.

Table 19: Results from Levene's test of equal variances

Levene's Test of Equality of Error Variances		
	F	Sig.
% non-White_0.5 Buffer_2000	4.631	0.04*
% non-White_1.0 Buffer_2000	15.959	0.01*
% non-White_1.0 Buffer_2009	17.368	0.00*
Housing Units_1.5 Buffer_2009	1.028	0.32
Educational Attainment_ 0.5 Buffer_00-09	0.065	0.80
Educational Attainment_ 1.5 Buffer_90-01	1.626	0.22
Median Household Income_0.5 Buffer_90-09	2.652	0.12
Median Household Income_0.5 Buffer_00-09	0.143	0.71
Households w/ Pub. Assist. Inc._ 1.5 Buffer_90-00	0.009	0.93

*Significant at $p<0.05$

In summary, all but one DV (housing units at 1.5 mile buffer and year 2009) fulfilled the first ex post assumption and all but three DVs (which are all percent non-White but at different distance intervals and different years) fulfilled the second ex post assumption. This reveals that there are factors that have influenced the results for percent non-white and housing units that were not accounted for in the MANCOVA. Future studies may need to incorporate additional CVs that could influence the results for housing units and percent non-White population change. Further discussion of future studies is provided in the next chapter 6 Conclusion.

CHAPTER 6: CONCLUSION

This chapter discusses the results from the cross-sectional and longitudinal analyses. In addition, there is a discussion on the implications of this research, the limitations of the research methods, and possible future studies that may provide more significant results that can answer questions regarding gentrification and brownfields.

6.1 Brownfields and Environmental Justice

Following completion of the cross-sectional analysis and the accompanied analytic tests, there is adequate evidence to answer the first research question. The questions asked if there are environmental justice issues associated with brownfields? The results indicate that yes, there is a disparity between the socio-economic character of populations that live near contaminated brownfields compared to the average population characteristics of the city, and thus supports Tiebout's (1956) theory. The theory predicts that low-income and minority households will be disproportionately impacted by environmental hazards due to their preference for public goods and housing costs. It is predicted that low-income households will sacrifice public goods (such as environmental quality) for affordable housing. The results of this research indicated that the theory holds true given that lower income and lower percent of homeownership was observed near contaminated brownfields.

The difference between areas adjacent to brownfields and the city for percent non-White population was not found to be statistically significant. Although, Figure 4 (p. 38) displays a noticeable difference between the two, with higher non-White population located in areas within the 0.5 mile buffer of brownfield. The two other variables, median household

income and owner occupied housing units, were both found to be statistically significant using the two-sample t-test.

Given that two of the three variables were found to be significantly different between the brownfields and cities, and the other variable shows a common trend of higher non-White population near brownfields, it can be concluded that there were environmental justice issues associated with brownfields prior to receiving funding. This finding provides an historical context for the next phase of this study, which is the longitudinal analysis and the study of gentrification. If these EPA pilot brownfields have significant differences in demographics compared to the cities average, then it can be hypothesized that gentrification of the low-income and minority populations can take place once the funds for clean-up and redevelopment are invested in the brownfields.

The results of the cross-sectional study are not surprising given that the EPA-BPP targeted areas with environmental justice issues (Solitare and Greenberg 2002). In addition, previous studies have found similar results and concluded that low-income and minority residents are often disproportionately exposed to environmental hazards such as brownfields (Gallagher and Jackson 2008). This study contributes to the existing literature that explores the relationship between brownfields and environmental justice because this study invested an area of the country (EPA Region 7) that has not received attention in the environmental justice and brownfields literature.

6.2 Brownfields Redevelopment and Gentrification

The phenomenon of gentrification was measured using 10 census variables over a span of 19 years and across three spatial extents. Through the use of MANCOVA, this study

concludes that gentrification has not occurred near redeveloped brownfields. While the data shows a significant increase in the socio-economic character of areas near brownfields (in terms of educational attainment and median household income), there was not a significant increase in housing stock, or significant decrease in minority population. The results actually show that housing stock and minority population changed in the opposite direction that was hypothesized. Thus, the results of the longitudinal analysis reveal that the EPA Brownfields Pilot Program has not contributed to gentrification near brownfields (research question two). In addition, the lack of significant differences between DVs across the three buffer distances does not allow this research to accurately answer the third research question (If gentrification has occurred, what is the spatial extent of the gentrification?).

Although there are few significant differences between the treatment and control groups, there are several interesting findings from the analysis. It is interesting to note that there is a lack of residential developments that occurred near the treatment brownfields. Only one of the 12 cities (Wichita, KS) constructed new housing on former brownfields. Considering Wichita, KS was one of two brownfields that did not require cleanup of contamination, it is not surprising that housing units were constructed since cleanup can increase redevelopment costs and slow the redevelopment process. Smith's (1979) rent-gap theory predicts that once the gap between the actual and potential value of property grows large enough, development of the most profitable land use will occur. If investment in the assessment and cleanup of brownfields did not spark the redevelopment of profitable land uses such as high priced condominiums or office buildings, then it could be the case that the potential ground rent is not at a high enough value to construct new housing.

It may be the case that the environmental stigma associated with brownfields is slowing the increase in potential ground rent. If an environmental stigma still exists in the area near a formerly contaminated brownfield, then there will be lower demand for properties near the brownfields. Brownfields that were once heavily contaminated and known around the community as a place that may cause human health risks, may still be seen as health risks even after cleanup. It is possible that the cities which have left the brownfield vacant or as an open green space, are waiting for the environmental stigma to subside and for the demand of properties near the brownfield to increase.

It is assumed that cities and local stakeholders are interested in redeveloping brownfields for profit because a recent review by the EPA's Office of Program Evaluation found that its own brownfields performance measures were designed only to take into account development and economic outcomes (DeSousa 2005). If performance measures are only concerned with economic and development outcomes, it would seem logical that redevelopment would be geared toward amenities that favor high income residents and land uses that can produce profits. Additionally, Cunningham (2002) reveals that the major misconception regarding brownfields redevelopment is that the primary purpose is for environmental clean-up. In reality, the principal driver of brownfields cleanup and redevelopment is economic and the ability to make a profit (Cunningham 2002).

In addition to the possible environmental stigma associated with brownfields, the economic and demographic characteristics of EPA Region 7 could be responsible for the lack of significant findings from the longitudinal analysis. Considering that the analysis only investigated two major metropolitan areas (St. Louis and Kansas City), there may have not been the demand for urban land and new developments similar to what would be expected

for large metropolitan areas that are experiencing urban growth. Cities such as Cedar Rapids, Clinton, Coralville, Bonne Terre, and Springfield are likely to not experience the development pressure of urban land similar to what is experienced in larger metropolitan areas. The potential lack of demand for urban land could account for the slow brownfield redevelopments seen for the treatment group.

6.3 Implications of Research

There are two major implications of this study: 1) by using a 19 year time frame for the analysis of gentrification, this study has contributed to the existing literature on gentrification and brownfields by using a time lapse analysis longer than previously used; and 2) through the investigation of EPA Region 7, this research has completed a study of an area which has received little attention from researchers who are interested in the relationship between brownfields and environmental justice, and also brownfields and gentrification.

Previous studies of gentrification have only investigated gentrification through the use of a 10 year time lapse analysis (Eckerd 2010; Essoka 2010; and Pearsal 2010). While this may be adequate, the use of a longer time frame may better determine the socio-economic outcomes of brownfield redevelopment given the average time to redevelop a brownfield (5 years) and the potential environmental stigma that may still exist long after cleanup. The use of ACS 5-year estimates is also an innovative approach to the study of gentrification. The significance of using the ACS 5-year estimates is that they are released on a yearly basis and it will allow future researchers to continuously track the socio-economic characteristics of redeveloped brownfields.

The research of EPA Region 7 is also significant because there is a lack of studies that have investigated brownfields within EPA Region 7. Research into Region 7 is important because over $2.4 million dollars of EPA pilot grant funding was allocated to this region. This suggests there is an abundance of brownfields within this Region and research into the outcomes of brownfields redevelopment is critical to understanding the possible transformation of urban centers and river fronts that were once contaminated properties.

6.4 Limitations of Research

There are two major limitations of this research. First and foremost is the modifiable areal unit problem (MAUP), which deals with the decision to use aggregated block group data as the spatial unit of analysis. The second limitation is the time period used to test for gentrification and the occurrence of a major economic recession that took place during the time lapse analysis. Further discussions of the aforementioned limitations are presented below.

Environmental justice and gentrification research are linked to the idea of space because it is the proximity to an "effect", such as environmental contamination, that ultimately determines the significance of results. Accordingly, the decision of which spatial unit of analysis is critical to accurately determine if environmental racism has occurred or if the phenomena of gentrification is an outcome of redevelopment. For example, evidence of environmental justice was found at the county level (U.S. GAO 1983) and zip code level (CRJ 1987), but later studies that used census tracts found evidence contradictory to the previous studies (Davidson and Anderton 2000). The choice of unit of analysis is related to the concept of modifiable areal unit problem (MAUP). The possibility of choosing several

spatial units to measure the same phenomena is the modifiable aspect of MAUP (Noonan et al. 2009). MAUP is composed of two parts: Scale Effect and Zonation Effect (Openshaw 1984). The scale effect is the variation of results that come from using sets of areal units that are aggregated into fewer and larger units of analysis (Openshaw 1984). For example, using census blocks as a unit of analysis will produce different results than if block groups were the unit of analysis. The zonation effect refers to how an area is divided into sub-units where boundaries are determined based on correlation of values (Noonan et al. 2009). The zonation problem arises because of uncertainty about how the data are aggregated to form a given number of zones. This leads to variation of results when alternative zonal configurations (of which have the same numbers of units) are used to measure the data (Openshaw 1984).

The choice to use block groups for the unit of analysis was made because block groups are the smallest unit of analysis available for the 1990 and 2000 census and the 2009 ACS 5-year estimates. The smallest unit of analysis was used because increasing the resolution of analysis can increase the sample size and reduce variance in the analysis (Noonan et al. 2009). The problem is that census data is aggregated in block groups and making conclusions based on data gathered at the block group level may not be consistent with conclusions gathered at larger or smaller units of analysis. As Noonon et al. (2009) notes, there is currently little theoretical or conceptual guidance in identifying the proper unit of analysis. Thus, it is up to the researcher to determine the spatial extent of the "effect" (e.g. environmental contamination or brownfield redevelopment) that is being measured and decide on a unit of analysis that will accurately measure the phenomena. This research used concentric circles at 0.5 mile intervals to measure gentrification because it was used in previous studies of gentrification (Essoka 2010). The question remains, would it be more

appropriate to measure beyond 1.5 mile or less than 0.5 mile? Since determining the spatial extend of the "effect" (EPA funding as part of the Brownfield Pilot Program) was not preformed prior to making the decision to use block groups as the unit of analysis, this study may have used an inappropriate unit of analysis.

The second major limitation of this research is the occurrence of a major economic recession during the time period under investigation as part of the longitudinal analysis. The National Bureau of Economic Research (NBER) stated that the United Stated entered into an economic recession during the beginning months of 2008 (Isidore 2008). NBER defines recession as "a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in income, employment, industrial production, and retail sales." (Isidore 2008, p.1). Measuring the change in socio-economic variables between 1990 and 2000 would not have been affected by the recession of 2008, but measuring the change from 2000 to 2009 and 1990 to 2009 might have been affected by the economic downtown. One of the key variables that ultimately led to the recession was the housing market downturn that started in 2006. The drastic decrease in housing prices resulted in fewer homes being built and fewer home purchases (Isidore 2008). Along with the crash of the housing market was a cut of over 1.2 million jobs in 2008 (Isidore 2008). Under normal economic conditions this research may have compiled different results for the socio-economic variables used to measure gentrification. Considering redevelopment of brownfields relies on private developers and local governments willing to invest in the revitalization of former derelict properties, the economic recession may have hindered the prospect of making a profit and thus reducing the incentive to invest. If stakeholders do not invest, fewer housing units will be constructed or renovated and more affluent residents will

be unwilling to move back to the central city. Using an extended time frame analysis beyond 2009 may provide results that are expected under normal economic conditions.

6.5 Future Studies

Future studies of gentrification and brownfield redevelopment could utilize different methodological approaches to more accurately measure gentrification. Some alterations to the data and spatial unit of analysis would result in a more accurate representation of socio-economic outcomes following redevelopment. In addition to alterations in the quantitative methods, future studies should incorporate qualitative research to determine the extent of environmental stigma and also gain a better understanding of the planning process utilized for redevelopment.

As previously stated, environmental stigma may have an impact on the development of former brownfields. Future research that incorporates qualitative methods may provide greater insight into the expected outcomes of redevelopment and also the time necessary for residents to accept that former brownfields are adequate for residential use. Through interviews with local residents and private developers, researchers could gain insight into the public's perceived hazards of brownfields. Interviews with private developers is also beneficial because they are often required in the redevelopment of brownfields and they would better understand the effects of contamination on demand for properties and how it impacts what land uses are developed on former brownfields. Additionally, interviews and surveys of local residents and stakeholders could provide a better understand of the effect that contamination has on adjacent properties and ultimately determine the proper spatial extent to measure. If it can be determined how contamination affects people's perception of

properties at varying distance intervals extending away from the brownfield, then it could be possible to limit the MAUP. The use of qualitative research prior to the quantitative analysis may enable researchers to accurately determine which variables to measure and what spatial unit will most accurately measure the effect.

This study used data from the census at the block group level. Future studies that use data at the block level could determine more accurately the changes in demographic variables around brownfields. Socio-economic variables are not provided at the block level but utilizing the 2010 census to measure the change in demographics at the block level would result in more accurate results. In addition to using a more accurate unit of analysis, extending the time frame of the study beyond 19 years may result in more significant findings. The brownfield redevelopments used in this analysis received funding between 1995 and 1999 and use of 2009 data may not have provided a long enough lapse of time (10-14 years) to fully analyze the outcomes of redevelopment. Since the ACS produces their 5-year estimates every year, future studies could continue to use the ACS data to measure the socio-economic change on a yearly basis.

Another strategy that future research could implement that would more accurately provide evidence for the relationship between gentrification and brownfield redevelopment would be the addition of multiple covariates (CVs) in the MANCOVA analysis. This research used population as a CV, but there are several other factors that could be controlled for that could reduce the error of the MANCOVA model. Other factors that might affect outcomes of brownfield redevelopment include, but are not limited to: the size of brownfields, the extent of contamination, the type of redevelopment (commercial, residential, mixed use, etc.), the total investment for redevelopment, and the location of the brownfield

(rural, urban, or near the central business district). These factors may influence the movement of populations following redevelopment and if they can be controlled for using MANCOVA, then researchers could more accurately pinpoint the variable that has the greatest influence on the socio-economic outcomes of brownfields redevelopment.

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Appendix A: Cross-Sectional Study Descriptive Statistics

Table 20: Descriptive Statistics of cross-sectional study for percent non-White population

% non-White		
	0.5 Mile Buffer	City
Mean	44.0	43.4
Median	29.9	8.3
Standard Deviation	37.6	378.3
Range	100.0	15,775.0
Minimum	0.0	0.0
Maximum	100.0	15775.0
Count	25.0	2049.0

Table 21: Descriptive statistics of cross-sectional study for median household income

Median Household Income		
	0.5 Mile Buffer	City
Mean	14,444.7	26,731.4
Median	13,836.0	24,630.0
Standard Deviation	5,849.7	13,703.6
Range	23,470.0	150,001.0
Minimum	5,030.0	0.0
Maximum	28,500.0	150,001.0
Count	25.0	2,049.0

Table 22: Descriptive statistics of cross-sectional study for percent owner occupied housing units

% Owner Occupied Housing Units		
	0.5 Mile Buffer	City
Mean	30.2	54.3
Median	27.3	56.3
Standard Deviation	23.2	26.3
Range	70.8	100.0
Minimum	0.0	0.0
Maximum	70.8	100.0
Count	25.0	2,049.0

Appendix B: Longitudinal Study Descriptive Statistics

Listed in the first column of Table 23 are the abbreviations for the dependent variables (DVs). The numbers 1-3 represent the three buffers used in the longitudinal analysis: 1 = 0.5 mile buffer, 2 = 1.0 mile buffer and 3 = 1.5 mile buffer. The number following the underscore is the year of the measurement: 09 = 2009, 00 = 2000, 90 = 1990, 90-00 = change from 1990-2000, 00-09 = change from 2000-2009, and 90-09 = change from 1990-2009. The abbreviations are explained below:

POP= Total Population

MIN= % non-White

EDU= Bachelor's Degree or higher education

INC= Median Household Income

HHPubAssist= Households with Public Assistance Income

HU= Total Housing Units

OOHU= % Owner Occupied Housing Units

ROHU= % Renter Occupied Housing Units

GrossRent= Gross Rent

HVAL= Median Value for Owner Occupied Housing Units

Table 23: Descriptive statistics of longitudinal study for all dependent variables

DVs	N	Range	Min.	Max.	Mean	Std. Deviation
POP1_09	22	7,929	475	8,404	1,832	1,802
POP2_09	24	26,981	560	27,541	6,454	5,745
POP3_09	24	50,910	854	51,764	10,706	10,384
MIN1_09	22	98	-	98	32	28
MIN2_09	24	92	2	94	28	27

Table 23: Continued

DVs	N	Range	Min.	Max.	Mean	Std. Deviation
MIN3_09	24	82	2	84	26	23
EDU1_09	22	29	-	29	9	7
EDU2_09	24	31	2	32	10	8
EDU3_09	24	33	5	38	11	7
INC1_09	22	40,437	11,688	52,125	28,594	9,323
INC2_09	24	57,575	16,688	74,263	31,479	11,612
INC3_09	24	66,154	23,671	89,825	35,664	14,064
HHPubAssist1_09	22	12	-	12	4	4
HHPubAssist2_09	24	16	-	16	5	4
HHPubAssist3_09	24	8	-	8	4	2
HU1_09	22	3,792	93	3,885	905	842
HU2_09	24	13,060	325	13,385	3,019	2,637
HU3_09	24	25,264	506	25,770	5,089	5,259
OOHU1_09	22	81	1	82	35	24
OOHU2_09	24	86	4	90	42	21
OOHU3_09	24	62	18	80	48	17
ROHU1_09	22	80	3	83	47	21
ROHU2_09	24	80	7	87	42	19
ROHU3_09	24	52	13	65	39	13
GrossRent1_09	21	649	341	990	584	167
GrossRent2_09	24	729	309	1,038	614	143
GrossRent3_09	24	813	55	868	602	154
HVAL1_09	19	109,095	2,330	111,425	64,128	29,345
HVAL2_09	24	172,000	31,750	203,750	94,665	37,195
HVAL3_09	24	157,866	39,625	197,491	97,530	35,866
POP1_00	22	7,621	433	8,054	1,935	1,715
POP2_00	24	25,131	755	25,886	6,423	5,437
POP3_00	24	36,860	1,069	37,929	10,384	8,529
MIN1_00	22	100	-	100	29	28
MIN2_00	24	98	-	98	26	30
MIN3_00	24	85	1	86	25	24
EDU1_00	22	21	1	21	8	6
EDU2_00	24	34	3	37	10	8
EDU3_00	24	25	5	30	10	6
INC1_00	22	25,328	16,768	42,096	28,019	7,307
INC2_00	24	61,272	18,592	79,865	33,913	12,876

Table 23: Continued

DVs	N	Range	Min.	Max.	Mean	Std. Deviation
INC3_00	24	38,483	24,043	62,526	38,253	8,762
HHPubAssist1_00	22	15	-	15	7	4
HHPubAssist2_00	24	21	-	21	7	4
HHPubAssist3_00	24	12	1	13	6	3
HU1_00	22	3,201	174	3,375	854	765
HU2_00	24	10,603	309	10,912	3,036	2,352
HU3_00	24	18,014	461	18,475	5,084	4,139
OOHU1_00	22	73	1	74	34	22
OOHU2_00	24	78	9	87	43	22
OOHU3_00	24	71	13	84	49	18
ROHU1_00	22	64	21	85	51	21
ROHU2_00	24	74	11	85	46	19
ROHU3_00	24	61	13	74	41	15
GrossRent1_00	22	349	313	662	486	98
GrossRent2_00	24	474	380	854	546	112
GrossRent3_00	24	390	432	822	569	96
HVAL1_00	22	113,025	17,342	130,367	63,245	28,239
HVAL2_00	24	163,817	31,955	195,772	81,306	39,211
HVAL3_00	24	128,821	36,958	165,778	78,861	28,147
POP1_90	22	6,999	667	7,666	2,111	1,667
POP2_90	24	24,754	716	25,470	6,486	5,325
POP3_90	24	38,926	1,134	40,060	10,730	9,179
MIN1_90	22	97	-	97	24	27
MIN2_90	24	97	-	97	19	28
MIN3_90	24	86	0	86	20	25
EDU1_90	22	26	-	26	8	7
EDU2_90	24	38	1	39	9	8
EDU3_90	24	26	3	29	9	6
INC1_90	22	29,264	8,058	37,323	24,470	7,122
INC2_90	24	60,232	17,770	78,002	31,895	12,922
INC3_90	24	32,791	20,613	53,404	33,498	8,777
HHPubAssist1_90	22	52	1	52	14	12
HHPubAssist2_90	24	34	2	36	12	8
HHPubAssist3_90	24	19	4	23	12	5
HU1_90	22	3,645	259	3,904	1,070	890
HU2_90	24	12,695	335	13,030	2,988	2,601
HU3_90	24	19,732	436	20,168	4,776	4,445

Table 23: Continued

DVs	N	Range	Min.	Max.	Mean	Std. Deviation
OOHU1_90	22	73	1	74	36	21
OOHU2_90	24	78	9	87	44	22
OOHU3_90	24	74	13	87	49	19
ROHU1_90	22	63	20	83	51	18
ROHU2_90	24	70	10	80	44	18
ROHU3_90	24	64	10	74	41	16
GrossRent1_90	22	317	288	606	479	83
GrossRent2_90	24	662	383	1,045	523	132
GrossRent3_90	24	340	431	771	550	94
HVAL1_90	21	85,959	-	85,959	42,723	20,289
HVAL2_90	24	114,573	29,836	144,410	62,129	28,136
HVAL3_90	24	108,090	33,636	141,726	64,025	23,991
POP1_90-00	22	1,753	(1,365)	388	(176)	422
POP2_90-00	24	5,068	(3,362)	1,706	(63)	1,104
POP3_90-00	24	6,988	(5,175)	1,813	(346)	1,387
MIN1_90-00	22	37	(9)	28	6	8
MIN2_90-00	24	32	(1)	31	8	8
MIN3_90-00	24	48	(19)	29	5	9
EDU1_90-00	22	17	(6)	12	0	4
EDU2_90-00	24	9	(2)	7	1	2
EDU3_90-00	24	8	(3)	5	1	2
INC1_90-00	22	31,116	(7,301)	23,815	3,549	7,201
INC2_90-00	24	16,965	(5,208)	11,757	2,242	4,556
INC3_90-00	24	17,433	(4,461)	12,972	4,755	4,080
HHPubAssist1_90-00	22	45	(41)	4	(8)	9
HHPubAssist2_90-00	24	17	(15)	2	(5)	5
HHPubAssist3_90-00	24	12	(12)	-	(6)	3
HU1_90-00	22	841	(727)	114	(217)	261
HU2_90-00	24	6,579	(2,118)	4,461	48	1,088
HU3_90-00	24	10,849	(1,693)	9,156	308	2,092
OOHU1_90-00	22	24	(16)	8	(2)	7
OOHU2_90-00	24	14	(7)	7	(2)	3
OOHU3_90-00	24	24	(8)	16	0	5
ROHU1_90-00	22	40	(23)	17	0	9

Table 23: Continued

DVs	N	Range	Min.	Max.	Mean	Std. Deviation
ROHU2_90-00	24	14	(5)	9	2	4
ROHU3_90-00	24	27	(17)	10	(0)	5
GrossRent1_90-00	22	545	(173)	373	8	100
GrossRent2_90-00	24	325	(191)	134	23	72
GrossRent3_90-00	24	324	(187)	137	19	72
HVAL1_90-00	22	133,259	(14,907)	118,352	22,464	31,292
HVAL2_90-00	24	149,355	(10,918)	138,437	19,176	29,233
HVAL3_90-00	24	56,780	(10,903)	45,878	14,836	14,703
POP1_00-09	22	1,625	(1,149)	476	(103)	390
POP2_00-09	24	3,649	(1,635)	2,014	32	847
POP3_00-09	24	16,268	(2,433)	13,835	322	3,189
MIN1_00-09	22	37	(18)	19	3	9
MIN2_00-09	24	21	(7)	14	1	5
MIN3_00-09	24	31	(14)	17	2	6
EDU1_00-09	22	37	(13)	23	1	8
EDU2_00-09	24	17	(5)	12	0	4
EDU3_00-09	24	21	(12)	9	1	4
INC1_00-09	22	21,801	(11,772)	10,029	575	6,211
INC2_00-09	24	29,067	(20,535)	8,532	(2,434)	6,807
INC3_00-09	24	67,343	(20,759)	46,583	(2,589)	12,147
HHPubAssist1_00-09	22	17	(11)	6	(3)	4
HHPubAssist2_00-09	24	21	(15)	6	(2)	5
HHPubAssist3_00-09	24	13	(10)	3	(2)	3
HU1_00-09	22	888	(256)	632	51	197
HU2_00-09	24	6,704	(4,231)	2,473	(17)	1,037
HU3_00-09	24	16,373	(9,078)	7,295	5	2,463
OOHU1_00-09	22	39	(15)	24	0	8
OOHU2_00-09	24	20	(13)	7	(1)	6
OOHU3_00-09	24	31	(24)	7	(1)	6
ROHU1_00-09	22	74	(37)	37	(4)	17
ROHU2_00-09	24	25	(17)	8	(4)	6
ROHU3_00-09	24	32	(14)	18	(2)	7
GrossRent1_00-09	21	369	(3)	366	99	103
GrossRent2_00-09	24	481	(100)	381	68	108

Table 23: Continued

DVs	N	Range	Min.	Max.	Mean	Std. Deviation
GrossRent3_00-09	24	737	(496)	242	33	139
HVAL1_00-09	19	76,134	(42,419)	33,715	770	22,479
HVAL2_00-09	24	136,217	(69,772)	66,445	13,360	24,103
HVAL3_00-09	24	152,853	(2,840)	150,013	18,669	30,611
POP1_90-09	22	2,118	(1,380)	738	(279)	566
POP2_90-09	24	6,930	(3,251)	3,679	(32)	1,445
POP3_90-09	24	19,020	(7,316)	11,704	(24)	3,240
MIN1_90-09	22	49	(5)	44	8	11
MIN2_90-09	24	37	(3)	34	9	8
MIN3_90-09	24	34	(3)	31	7	7
EDU1_90-09	24	38	(18)	20	1	8
EDU2_90-09	24	18	(7)	12	1	4
EDU3_90-09	24	19	(10)	9	2	3
INC1_90-09	22	52,196	(18,352)	33,844	4,124	9,929
INC2_90-09	24	22,648	(13,976)	8,672	(416)	5,805
INC3_90-09	24	60,630	(11,456)	49,175	2,166	10,996
HHPubAssist1_90-09	22	56	(52)	4	(11)	12
HHPubAssist2_90-09	24	32	(30)	2	(7)	7
HHPubAssist3_90-09	24	18	(20)	(2)	(8)	5
HU1_90-09	22	941	(793)	148	(166)	260
HU2_90-09	24	2,143	(1,073)	1,070	31	442
HU3_90-09	24	6,355	(753)	5,602	313	1,327
OOHU1_90-09	22	31	(17)	14	(1)	8
OOHU2_90-09	24	32	(19)	13	(2)	7
OOHU3_90-09	24	19	(10)	9	(1)	5
ROHU1_90-09	22	66	(34)	32	(4)	15
ROHU2_90-09	24	29	(14)	15	(2)	6
ROHU3_90-09	24	25	(13)	12	(3)	7
GrossRent1_90-09	21	704	(86)	618	105	165
GrossRent2_90-09	24	532	(186)	346	91	110
GrossRent3_90-09	24	584	(383)	201	52	117
HVAL1_90-09	19	114,608	(22,923)	91,685	22,870	26,122
HVAL2_90-09	24	114,239	(12,750)	101,489	32,536	25,591
HVAL3_90-09	24	158,979	(1,180)	157,799	33,505	32,013

Appendix C: Trends Observed in Longitudinal Dependent Variables

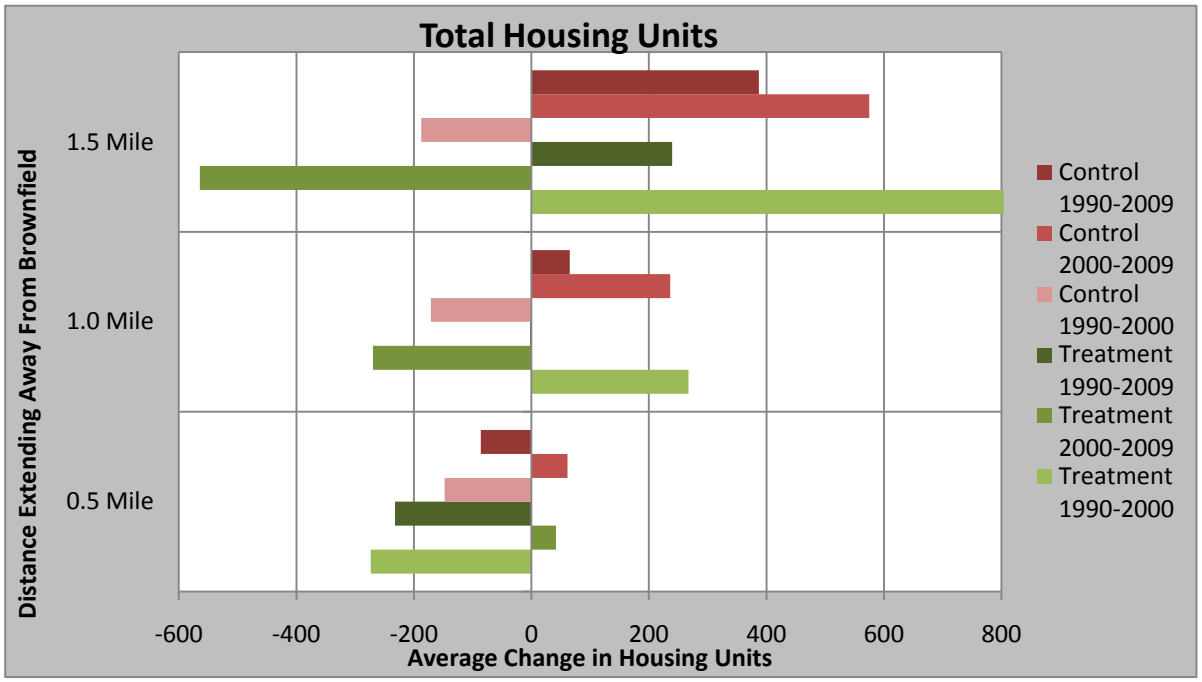

Figure 11: Average change in total housing units for treatment and control groups

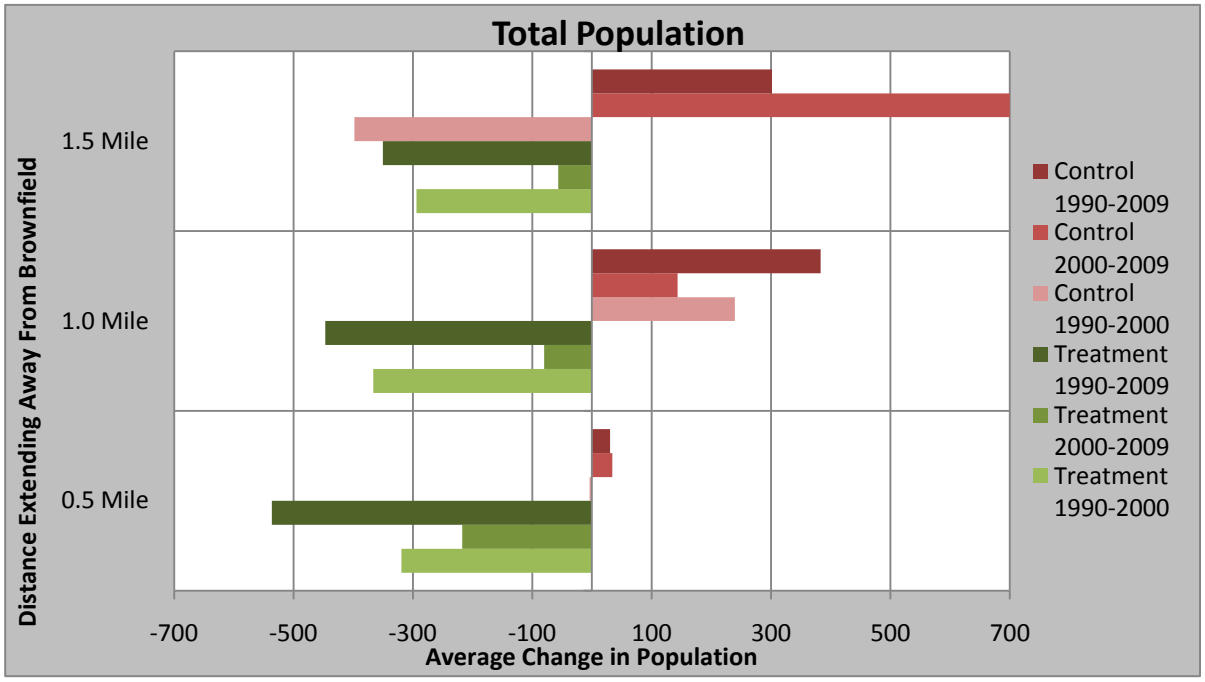

Figure 12: Average change in total population for treatment and control groups

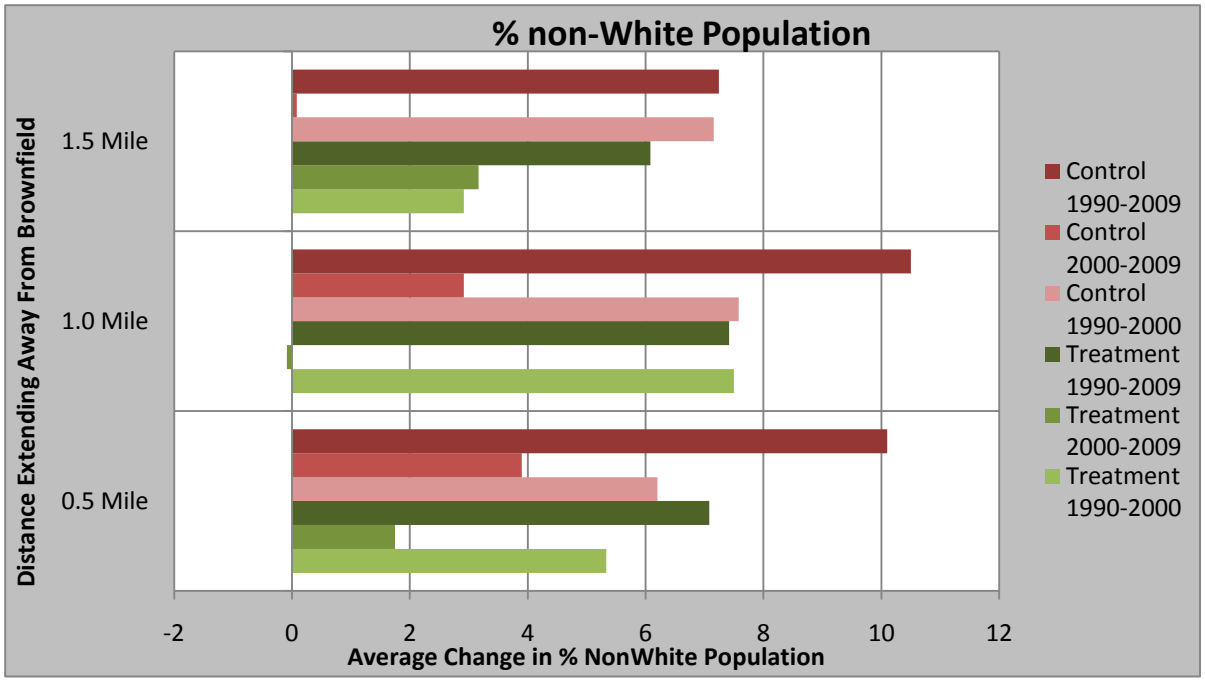

Figure 13: Average change in % non-White for treatment and control groups

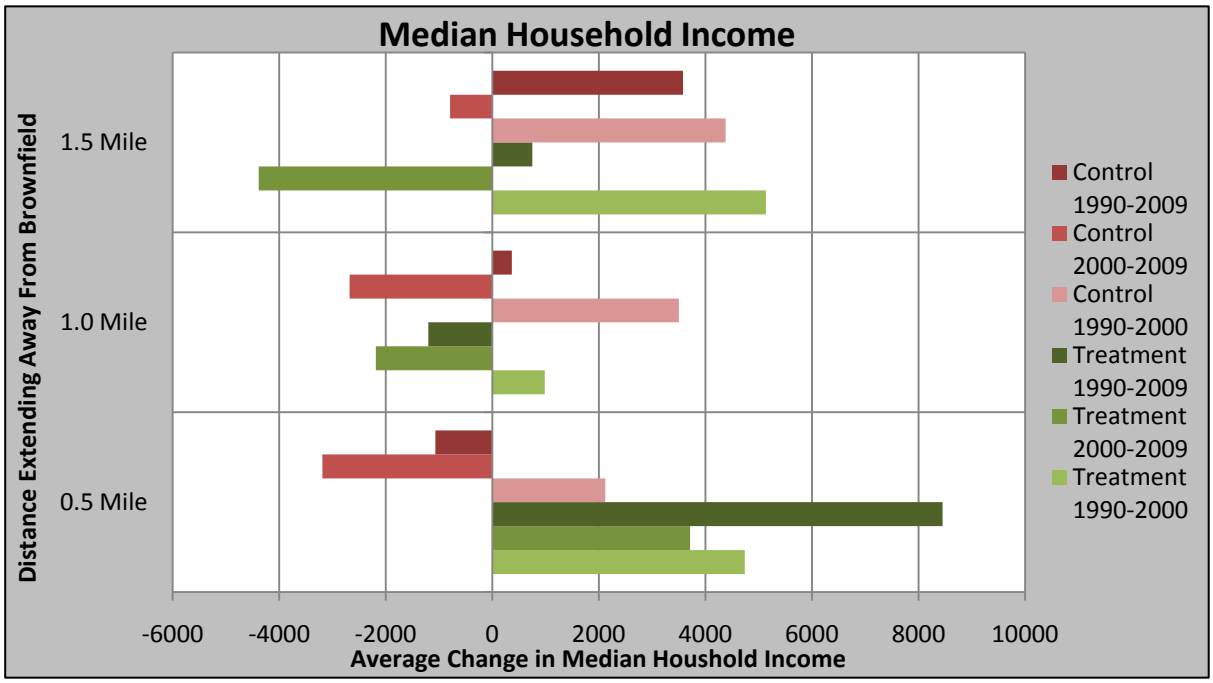

Figure 14: Average change in median household income for treatment and control groups

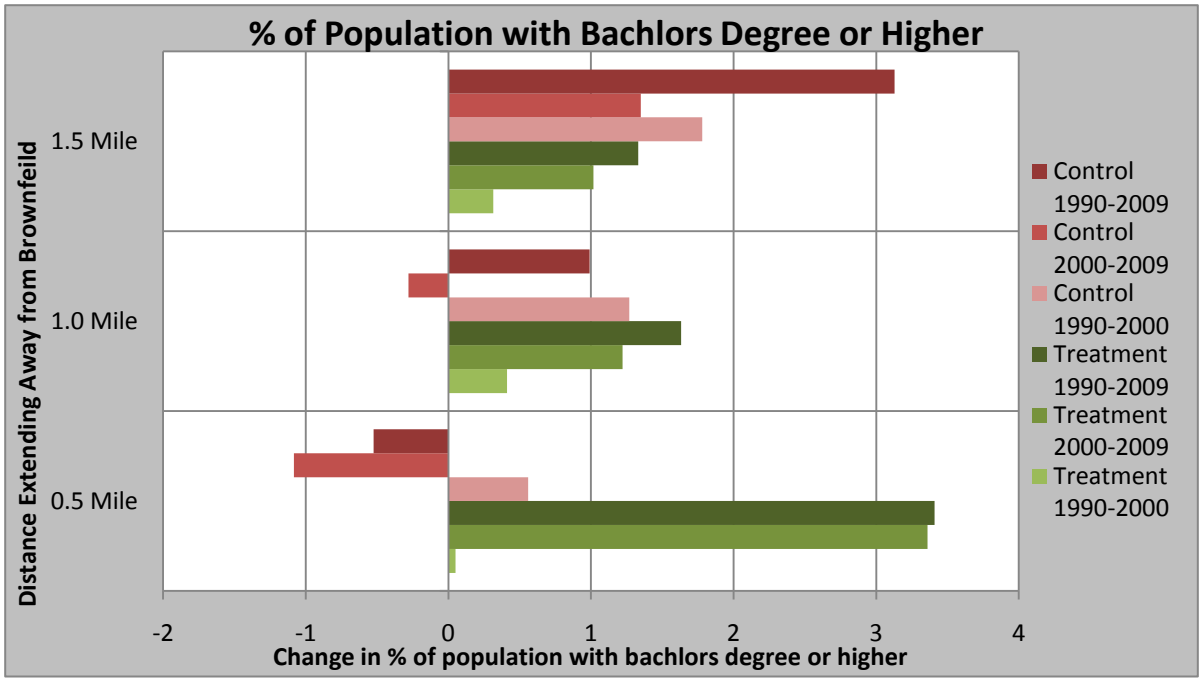

Figure 15: Average change in educational attainment for treatment and control groups

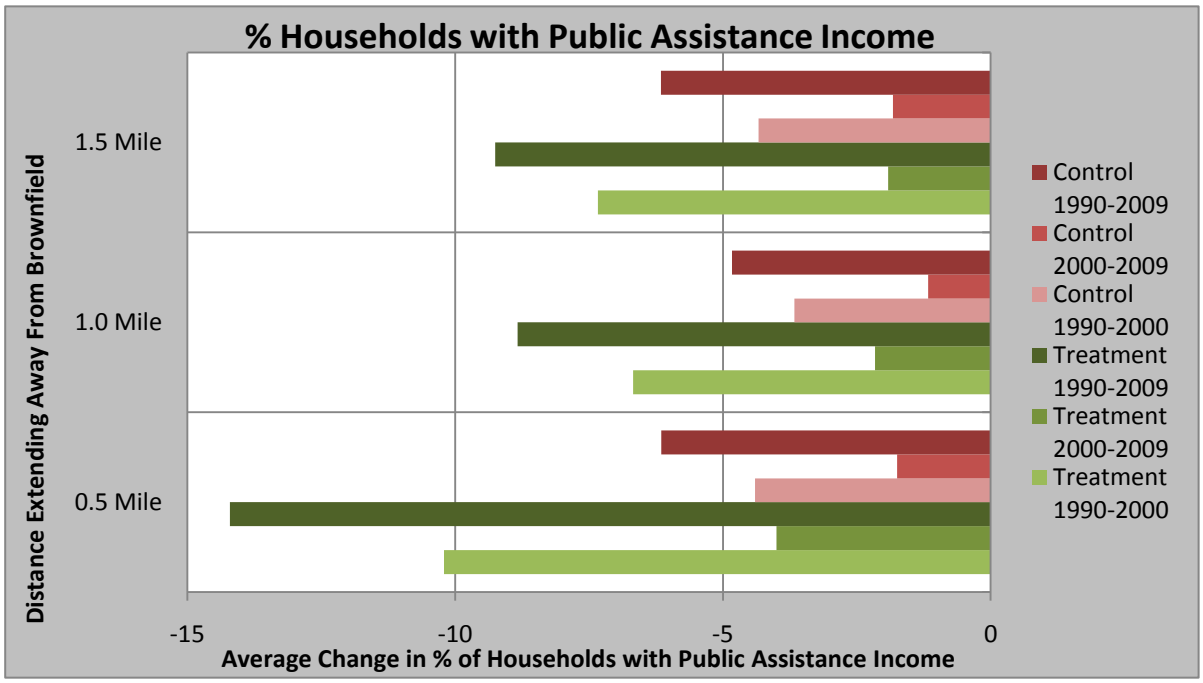

Figure 16: Average change in households with public assistance for treatment and control groups

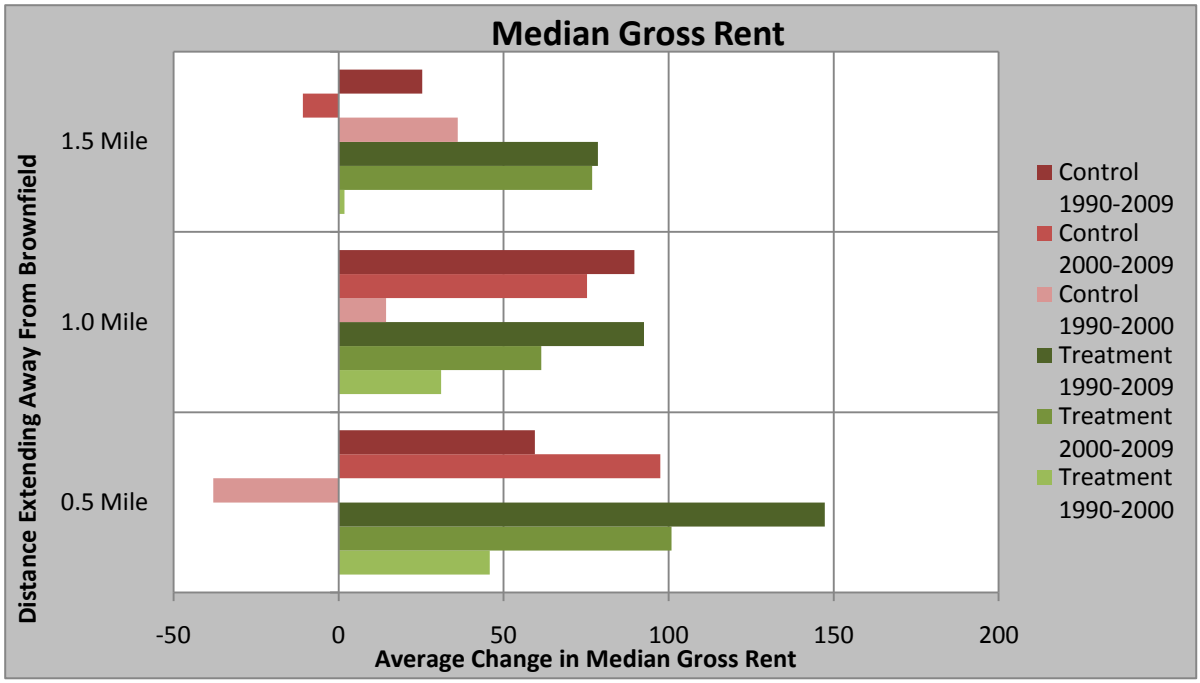

Figure 17: Average change in median gross rent for treatment and control groups

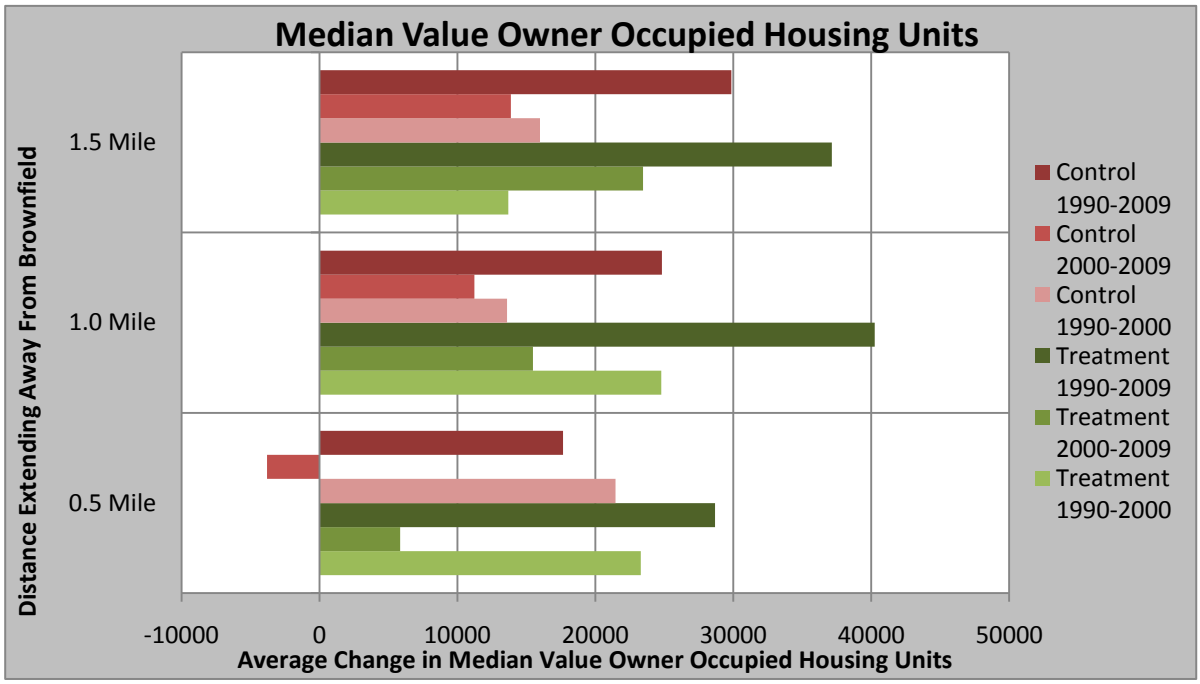

Figure 18: Average change in household value for treatment and control groups

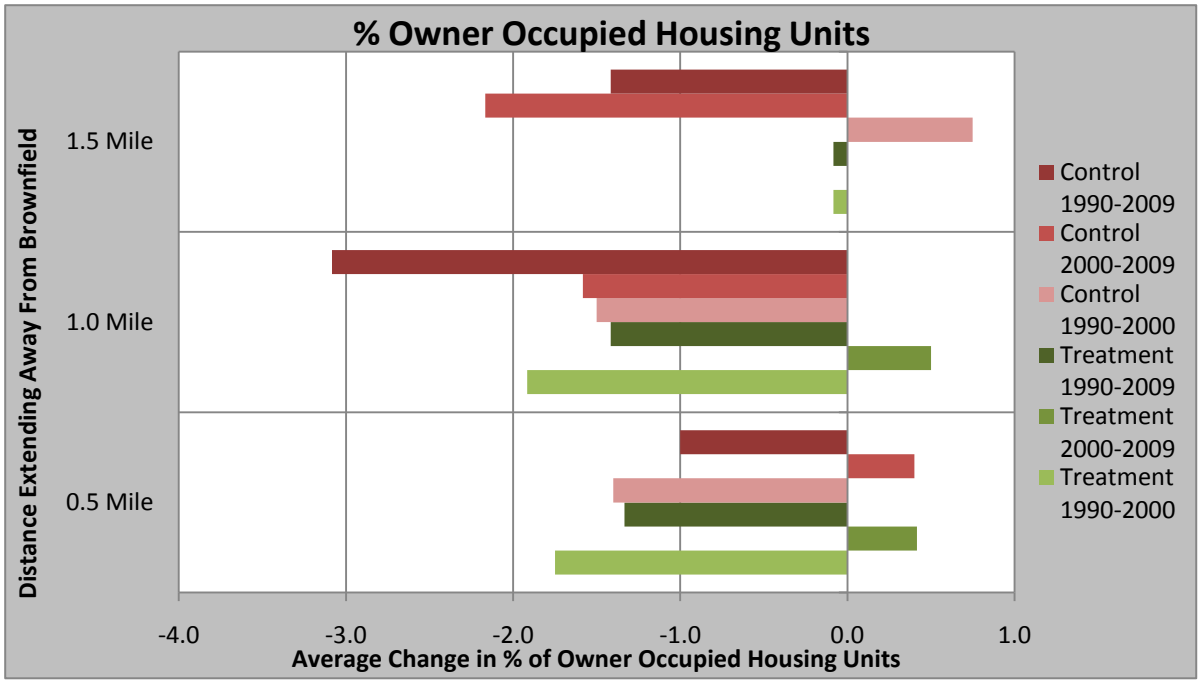

Figure 19: Average change in owner occupied housing for treatment and control groups

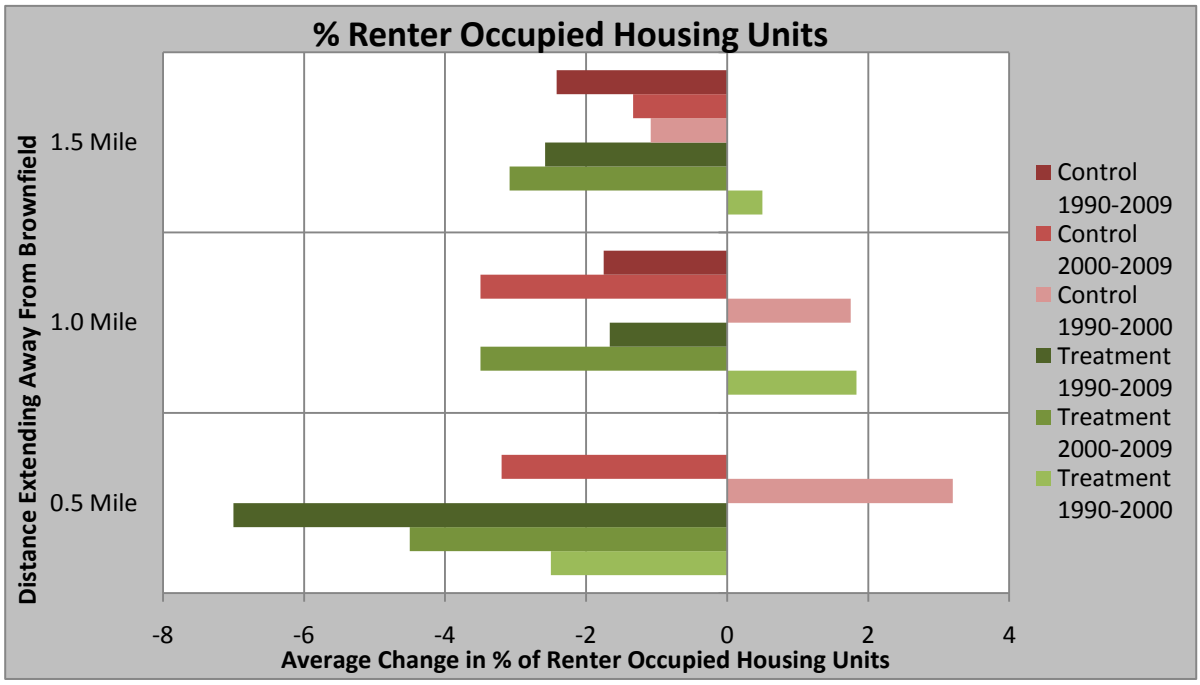

Figure 20: Average change in renter occupied housing for treatment and control groups

Appendix D: Histograms of Standardized Residuals

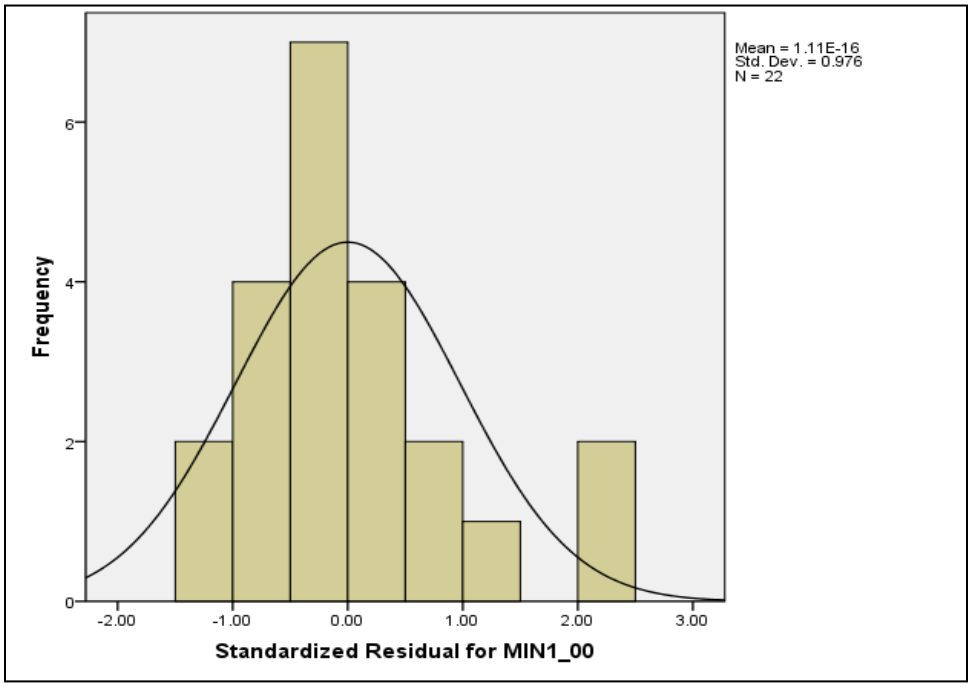

Figure 21: percent non-white, 0.5 mile buffer and year 2000

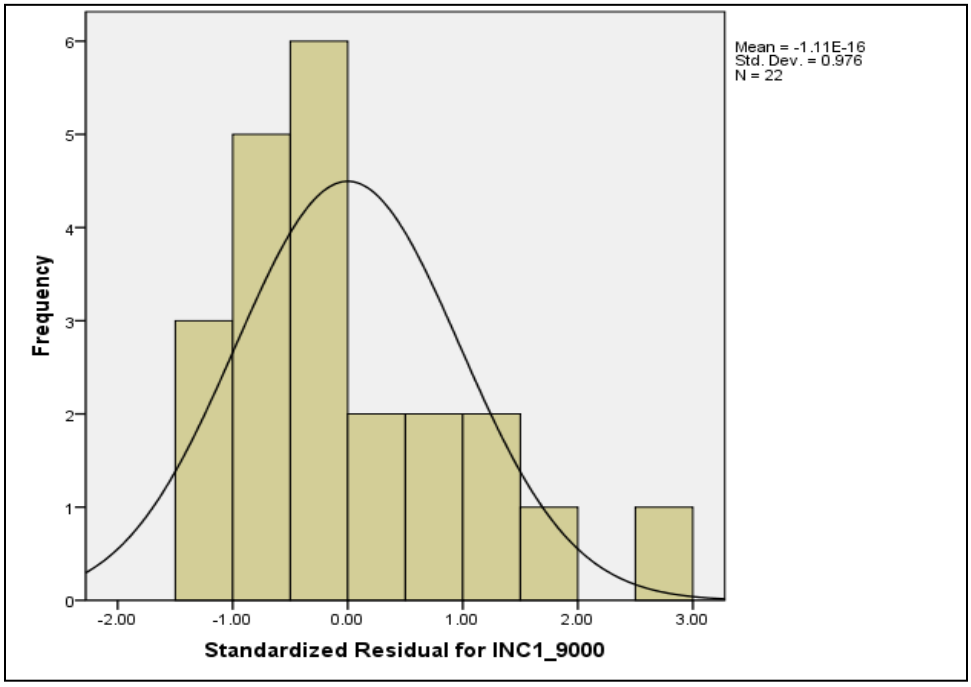

Figure 22: Median household income, 0.5 mile buffer and change from years 1990-2000

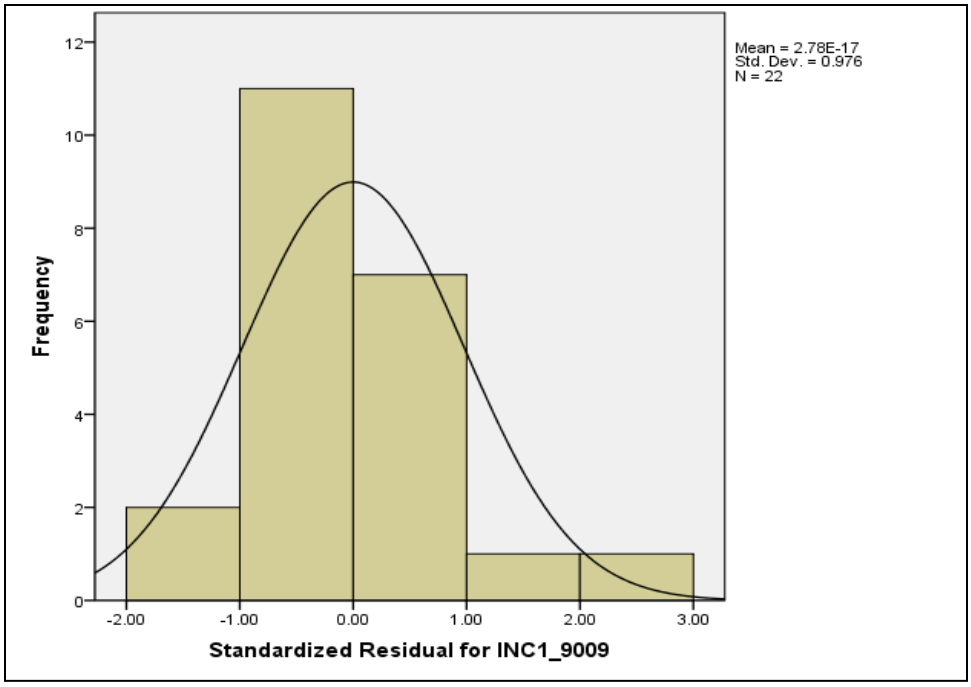

Figure 23: Median household income, 0.5 mile buffer and change from year 1990-2009

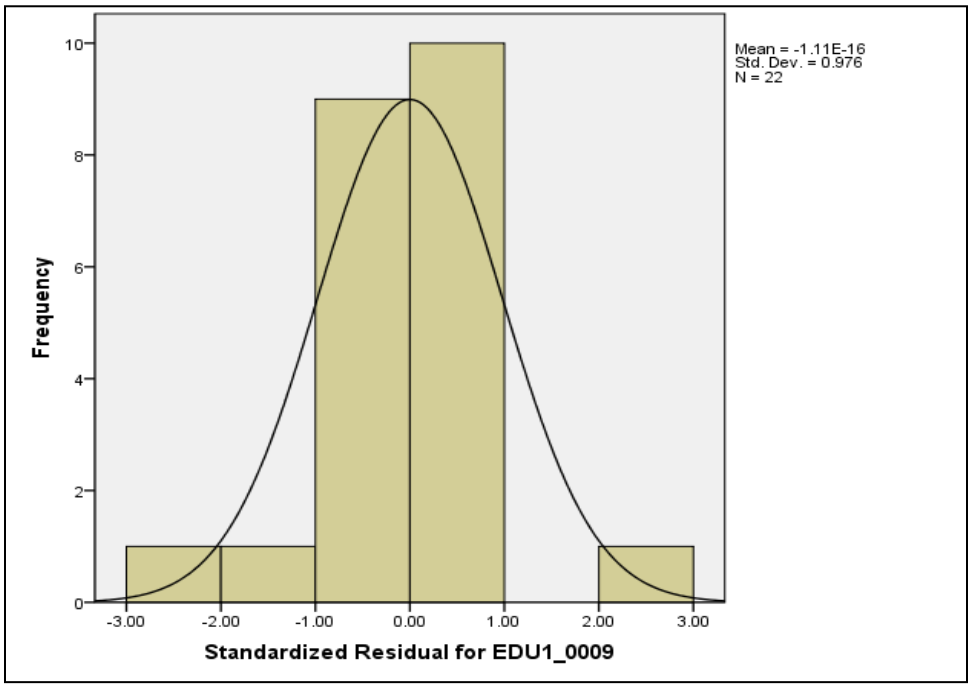

Figure 24: Educational attainment, 0.5 mile buffer and change from years 2000-2009

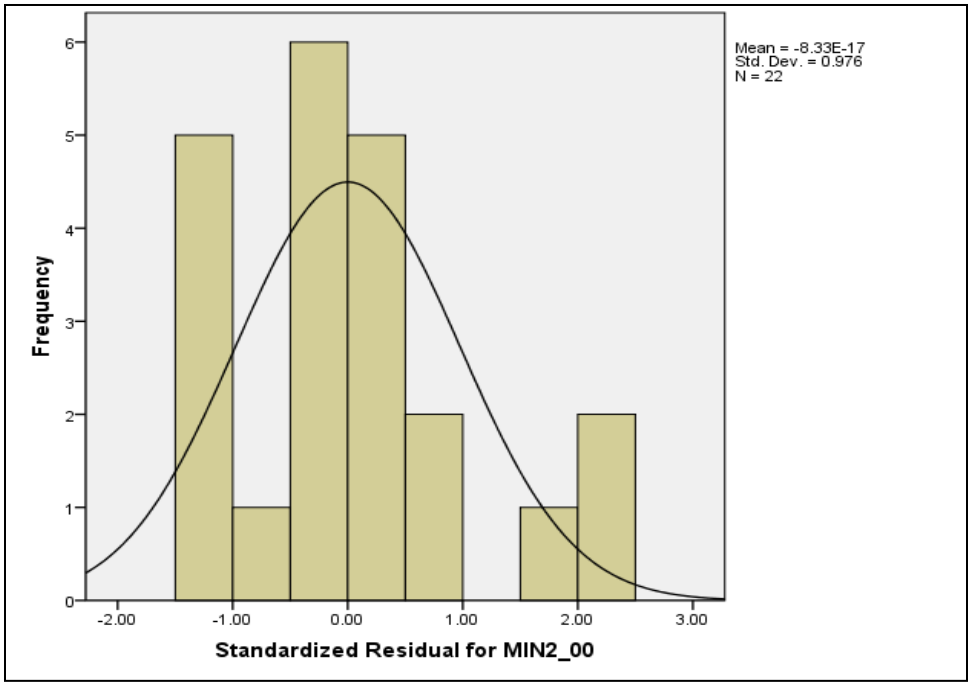

Figure 25: Percent non-White population, 1.0 mile buffer and year 2000

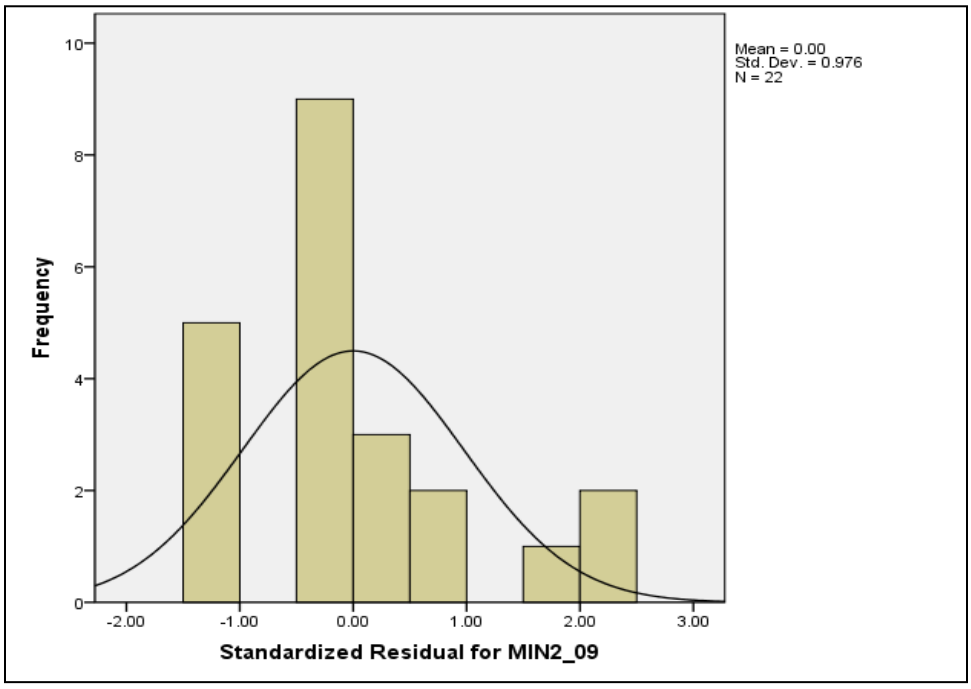

Figure 26: Percent non-White population, 1.0 mile buffer and year 2009

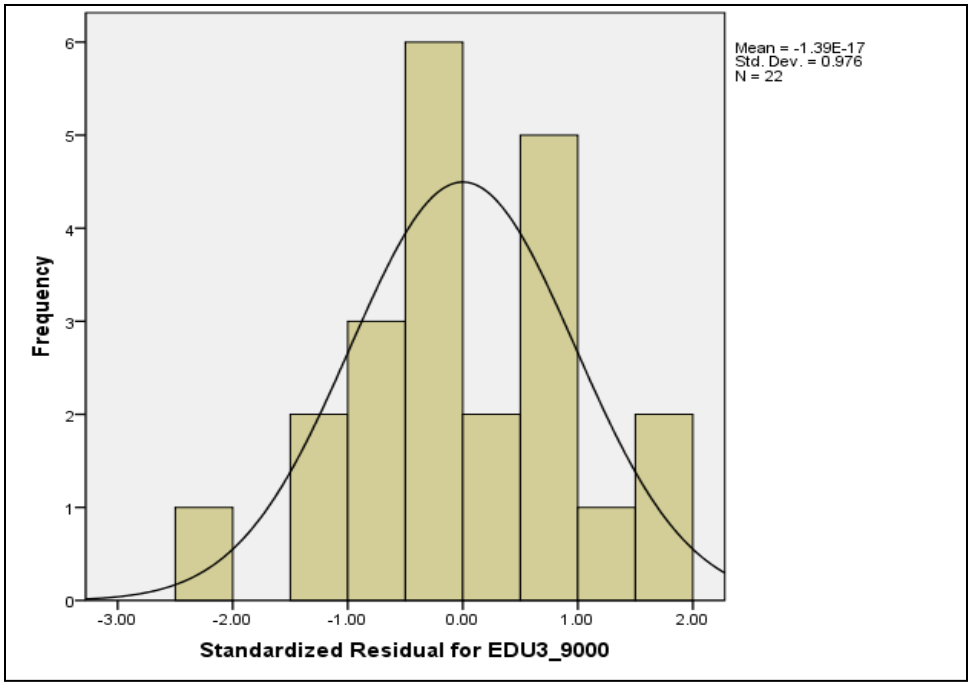

Figure 27: Educational attainment, 1.5 mile buffer and change from years 1990-2000

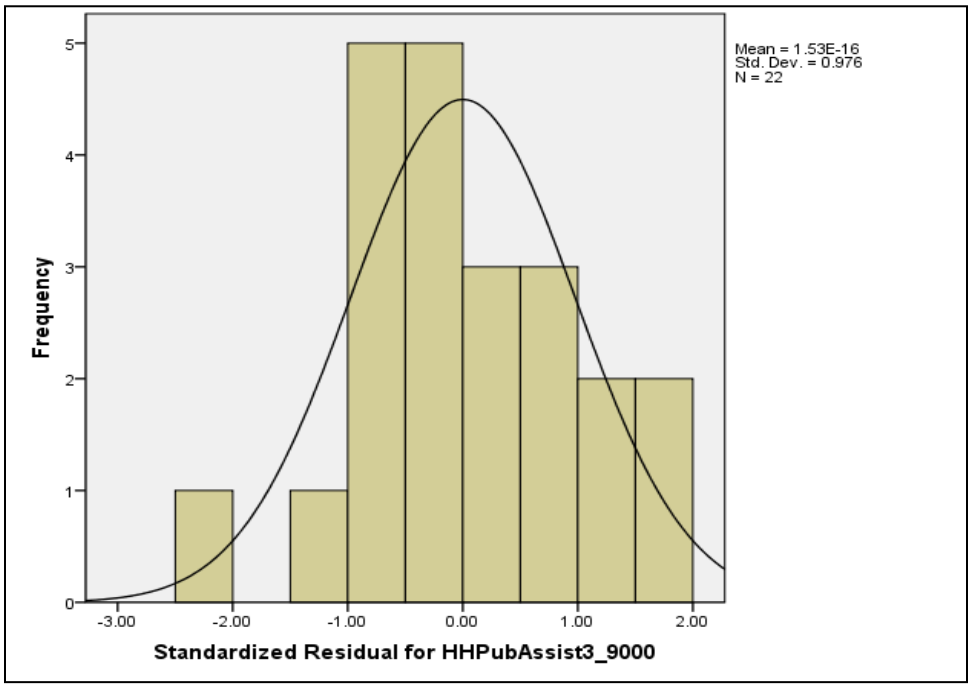

Figure 28: Households w/ public assistance, 1.5 mile buffer and change from years 1990-2000