Estimating the Effects of Brownfields and Brownfield Remediation on Property Values in a New South City*

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Abstract

This paper examines the effects of brownfields, constructive notice, and actual brownfield remediation on residential property sales values using data from Charlotte, NC. Charlotte offers an opportunity to examine whether the effects on property values of proximity to a brownfield, and subsequent application to voluntarily join a brownfield program and to later remediate any contamination are comparable to cities with more severe contamination. Using the most common measure of brownfield effects-- distance from the brownfield -- we generally find no effect, either by itself or interacted with other variables related to brownfields. But we do find significant effects for brownfield size, constructive notice—a developer has filed for permission to clean up the brownfield – and brownfield remediation. Property values decrease with brownfield size for up to one mile. They increase with constructive notice up to two miles (the maximum distance), but the largest effect is within 0.3 miles. Brownfield remediation has a positive effect that is significant in most cases, although smaller than the effect of constructive notice, beginning 0.5 miles from the brownfield, but a large and significant negative effect within 0.3 miles. Our results are consistent whether we examine all property values within a given distance, such as 0.5 miles, or examine discrete distances, such as 0.3 to 0.5 miles. The estimated benefits are on the order of $4 million.

JEL Classifications

Q51 - Valuation of Environmental Effects

Q24 – Land

Q28 - Government Policy

R52 - Land Use and Other Regulations

1. Introduction

Does the remediation of brownfields have any effect on nearby property values in cities that are growing geographically and that have a history of light industry? Developers in such an urban area can easily acquire land along the outer edges of the city, thus eliminating the potential extra costs associated with assessing and cleaning the brownfield, while the public benefit of remediating an otherwise idle property may be too slight or too hidden in a city with little or no history of heavy (and potentially more contaminating) industry to have much effect on property values. Yet supporters of urban brownfield revitalization suggest that there are benefits to remediating and redeveloping brownfields within cities and that these benefits outweigh potential costs. Additionally, supporters assert that public programs should allocate funding to encourage—and help pay for—remediation and redevelopment activities without imposing any conditions regarding the type of urban area being considered, be it New South, Midwest, or Northeast. In order to determine the desirability of such programs, it is necessary to have an estimate of program benefits which can then be compared to the costs.

On the surface, government assistance may not appear to be necessary. One could conceptualize the Coase Theorem as applying. Transactions involving contaminated land will discount the property value based on buyer and seller knowledge of contamination and cleanup costs. However, there is a well-developed literature identifying potential market failures that motivate a possible role for government assistance, including uncertainty, imperfect detection of contamination, judgment-proof buyers, and asymmetric information on the amount of contamination between buyer and seller.[1]

[1] Boyd, Harrington, and MacAuley (1996), Segerson (1997), and Corona and Segerson (2006) provide models of the real-estate market for contaminated properties.

This paper presents a study that estimates the benefit of brownfield remediation on sales prices of residential properties in Charlotte, NC, between 1997 and 2005. As used in this study, remediation means active cleaning of a contaminated property to the level necessary for its intended reuse, finding no contamination during assessment of property perceived as a brownfield based on historical use, or establishing land reuse restrictions or engineered barriers (or both) in lieu of active cleaning. The study uses the hedonic technique to examine the effect of brownfields and their anticipated and actual remediation on property values.[2]

The paper proceeds as follows. This introductory section provides a brief background of federal and state brownfields legislation as well as an explanation for using Charlotte as a representative New South city with geographical growth potential and a history of light industry. Section II is a review of relevant literature. Section III contains the estimating model, a discussion of the data, and the hypotheses to be tested. Section IV presents and discusses the results. Section V contains conclusions, policy implications, and suggestions for future research.

The term `brownfield' means 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. Estimates of the number of brownfields vary widely, with some estimates as high as 450,000, depending in particular on whether or not petroleum properties are included.[3] Brownfields are less contaminated than the severely contaminated "Superfund" properties, which are subject to joint, several, and retroactive liability as specified in the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).[4]

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[2] While we would also like to be able to examine the effects of redevelopment, there is sufficient heterogeneity in the types of redevelopment that we set that issue aside for future research. In addition, brownfield redevelopment is relatively recent, resulting in a small sample size of sales values post redevelopment.

[3] The Brownfields Site definition is found in Public Law 107-118 (H.R. 2869) - The number of estimated properties can be found at http://www.epa.gov/oust/petroleumbrownfields/pbfaqs.htm, which indicates that up to half of all brownfields may be petroleum brownfields.

[4] 42 USC § 9601-9675 (1980).

Nevertheless, it is suspected that many of these less-contaminated properties were idled or abandoned, for fear of possible CERCLA liability. In the late 1980s and early 1990s, several states established their own requirements for assessing and cleaning brownfields, which also included some form of limited liability guarantee for the developer who revitalized a brownfield. In 1995, the U.S. Environmental Protection Agency (EPA) initiated a brownfields redevelopment program to counteract the liability concern. In 2002, parts of the EPA program were codified into the federal Small Business Liability Relief and Brownfields Revitalization Act.[5]

In 1997, the NC Brownfields Program was established under the NC Brownfields Property Reuse Act (BPRA).[6] Potential developers can submit an application with the NC Department of Environment and Natural Resources (NCDENR) to participate in this program. If the property and proposed reuse are deemed eligible, the agency and potential developer negotiate and enter into a Brownfields Agreement (BFA) that identifies the proposed reuse of the property and specifies the actions considered necessary to make the property suitable for the proposed reuse (NCDENR, 2013).[7] In return for the potential developer committing to these actions, the agency agrees to hold the potential developer liable only for those actions listed in the BFA. Thus the potential developer goes from having an open-ended liability to having a known and limited liability, making it easier for the potential developer to obtain funding for remediation and redevelopment. The process to obtain the BFA requires substantial time and monetary commitments from the potential developer so it is reasonable to assume that a potential developer would choose to submit an application only if it truly plans to do the necessary remediation and redevelopment that may be required in the BFA.

[5] "Small Business Liability Relief and Brownfields Revitalization Act" signed into law January 11, 2002.
[6] NCGS 130A310.30 *et seq*, 1997
[7] The first BFA was applied for in January 1997 and signed in April 1998.

Since 1996, Charlotte has received $1 million in EPA assessment grants and other funding. Creating the Business Corridor Revitalization Area (BCRA) to focus its brownfields efforts, Charlotte city government aggressively pursued funding to assess potential brownfield sites for future redevelopment. The BCRA contains over 400 potential brownfield sites, most of which are believed to be lightly contaminated. Additionally, the same area has 200 miles of small waterways that could be contaminated with runoff from the brownfields, threatening the health and safety of those living within the BCRA, those who use the more than 1,400 acres of park and greenspace within the BCRA, as well as the drinking water of those living downstream (EPA, 2010).[8]

In 1996, Charlotte became the first city in North Carolina to be awarded an EPA brownfield assessment grant (EPA, 2013). The $200,000 grant funded the assessment of abandoned textile mills and other industrial properties along South Boulevard, a main artery leading to the central business district. The EPA grant was followed by negotiations with the NCDENR within the framework of the BPRA. The developer received the limited liability protection offered by the BPRA in return for restricting the use of contaminated groundwater on the property. Thus, the redevelopment of Camden Square became the first project under the new North Carolina Brownfields Program (EPA, 2006).[9]

This study using data from Charlotte, NC adds to the modest number of analytic studies estimating the benefits of brownfield remediation and redevelopment. Charlotte is representative of “New South” post-industrial cities that are more likely to have lightly contaminated properties than heavily contaminated sites in municipalities in the Northeast and Midwest. During the

[8] USEPA, “Brownfields 2010 Assessment Grant Fact Sheet: Charlotte NC. http://cfpub.epa.gov/bf_factsheets/gfs/index.cfm?xpg_id=7206&display_type=HTML, accessed Oct. 31, 2013.
[9] Today, the Camden Square project includes a $14.5 million Design Center of the Carolinas and the combined $49 million Village West complex, housing the UNC Charlotte School of Architecture design studios along with other businesses, and the Village East complex offering residential condominiums and apartments.

period of study, Charlotte became a center for financial services and headquarters for two of the largest banks in the US. It experienced population growth as people moved to the area to work in the financial and other service sectors. The city also had few geographical limits and could expand outward as necessary to accommodate the growing population. Finally, Charlotte has a history of little or no heavy industries; most of the suspected brownfield sites were warehouses, R&D facilities, commercial properties, and textile mills. For these reasons, Charlotte allows an opportunity to examine the benefit of brownfields remediation in a different urban context.[10]

2. Selected Literature on the Effects of Contaminated Properties and their Remediation and Redevelopment on Property Values

Contaminated properties are likely to reduce property values. As these properties are remediated, the negative effect is likely to be offset partially or completely. With redevelopment, property values will likely increase further, and the net effect could be positive. There is a growing literature pertaining to the effects of contaminated properties, including brownfields, on property values. There are a number of studies that examine the effect on property values of remediating brownfield sites.

While we do not estimate the effects of brownfield redevelopment in this study, we think it is worth noting the obstacles to such an effort. Wernstedt (2004) has suggested some possible reasons for the lack of brownfield redevelopment studies. The first is that brownfield redevelopment is quite recent, so there is little data on brownfields post-development. Hence, the few studies that portend to provide benefits of redevelopment may be unable to separate the benefits of remediation from those of reuse. A second possible explanation is that each

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[10] Many of the previous studies were done in older, more industrialized cities with limited geographical growth possibilities such as Milwaukee and Minneapolis (DeSousa, Wu & Westphal, (2009)), Baltimore (Longo and Alberini (2006)), and Chicago and surrounding areas (Linn (2013)).

brownfield has unique circumstances, so that it is not possible to provide a general method for estimating brownfield redevelopment. In this literature survey, we review literature relevant to estimating economic effects of brownfields, brownfield remediation, and for completeness, brownfield redevelopment.

Joel Corona (2004) and other hedonic studies typically model the effect of contamination on property values based on distance from the contaminated or potentially contaminated site. Using Connecticut data for 1990 through 2000 on brownfield locations and housing sales prices, he finds that property values increase at a decreasing rate with distance from the nearest undeveloped brownfield. After redevelopment, some samples show the distance effect mitigated, although not eliminated. This result suggests that while brownfield redevelopment improves property values, some stigma still remains. However, for some other properties, the distance effect actually increases after redevelopment, a surprising finding. Corona suggests two explanations: heightened awareness strengthening stigma, and increased traffic congestion. He is able to test the second hypothesis, and rejects it, leaving the awareness effect as the remaining possibility.

Leigh and Coffin (2005) studied effects of brownfield redevelopment in Cleveland and Atlanta. They found that small properties or ones located in depressed neighborhoods are likely to be overlooked due to public sector emphasis on allocating scarce resources to properties that will realize the greatest market returns. Surrounding properties may be stigmatized. The authors emphasize that their database contains known and potential brownfields. The latter is based on historical land use, including leaking underground storage tanks. The authors also emphasize their use of a threshold modeling strategy to capture neighborhood effects, such as grouping brownfields within 500 to 1000 feet from a property. The results confirm that brownfields have a negative impact on surrounding property and the neighborhood.

Kaufman and Cloutier (2005) study the Lincoln neighborhood in Kenosha, WI, a neighborhood that was declining but had the potential to turn a corner due to a housing program. There were two brownfields and one park in the neighborhood. There were 890 properties, of which about 150 sold in either 1999 or 2000. If the property did not sell, the authors used assessed value. Properties increased by $1341-$4842 on the average if there were no brownfields, and by $2700-$8000 where both properties were redeveloped as parks. This result assumes no diminishing returns for additional parks, and that people who live near brownfields are not those who place a minimum value on brownfields.

Kiel (2007) makes the point that it is necessary to observe the relationship between property value and distance from the contaminated site over time to see if the market has completely adjusted to such a site. If the sign remains negative, the sight remains a negative externality; i.e. stigma exists. She estimates the regression for 8 time periods from prior to announcement until development began.[11] Distance is positive and significant for 5 of the 8 regressions. It is not significant in the early stages, consistent with individuals being unaware of pollution. Marginal benefit is largest in the final period. Stigma remains, as prices are lower than prior to announcement. Next, Kiel's study looks at rate of appreciation. Time trend statistics are insignificant for the last 4 periods, suggesting the market is in equilibrium.

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[11] Kiel's study touches upon what happens once development begins, something Wernstedt believes studies have generally not distinguished from the cleanup phase. Her study not only has cleanup—it has cleanup announcement, cleanup begun, final investigation, followed by development of area. As mentioned earlier, Corona also includes brownfield redevelopment.

One problem with estimating the effects of brownfields and brownfield remediation and redevelopment is the difficulty of creating a useful control group. Greenstone and Gallagher (2008) were able to do so for the more severely contaminated properties that may qualify as Superfund sites, by comparing sets of properties where contamination did not vary significantly, but some were placed on the lower tier Superfund National Priority List (NPL) while others were just below the minimum to qualify for the list. That quasi-natural experiment offered a chance for a counterfactual. Prices of properties placed on the NPL were found to increase, but their study did not find a significant difference between the rate of price increase between those properties and other contaminated properties that were not placed on the list. While Greenstone & Gallagher were able to create a control group using Superfund requirements, their method is not transferable to brownfields, where there is no such list.

Noonan, Krupka, and Baden (2007) re-examine the Greenstone-Gallagher hypotheses using panel data as well as allowing for endogenous changes in environmental variables and neighborhood. Nevertheless, they too find Superfund cleanup had small and inconsistent effects.

Longo and Alberini (2005) note that in order to get total benefits from brownfield redevelopment, we would need to include commercial and industrial redevelopment as well as residential redevelopment. Surprisingly, the authors find commercial and industrial properties are virtually unaffected by proximity to a site with a history of contamination. They find no rebound effect from discovering that a site is no longer contaminated. Furthermore, the size of the site did not matter. They conclude that brownfield properties in Baltimore are not particularly attractive investments for developers, and there is little potential for self-sustaining cleanups, such as tax-increment financing (TIFs). It is doubtful that "one size fits all" measures to encourage the cleanup of contaminated sites can be successful in this context.

Ihlanfeldt and Taylor (2004) examine the effect of small-scale hazardous waste sites on commercial and industrial properties in Atlanta, GA. They find a sizable impact on property values, enough to suggest that TIF might prove worthwhile as an approach to encourage brownfield remediation and redevelopment.

DeSousa, Wu, and Westphal (2009) looked at how redevelopment of brownfields affected nearby residential property values in Milwaukee and Minneapolis. They incorporated a hedonic study along with qualitative analysis using interviews of relevant participants in the real estate markets in both cities (to determine the perceived impact of the redevelopment on the housing markets). Through the hedonic study, they found that brownfield redevelopment had significant positive effects on property values in both cities (11% in Milwaukee and 3% in Minneapolis).

Finally, a recent study by Linn (2013) examines the effects on nearby property values of a voluntary redevelopment program in Illinois. Property owners enter the program to have their property evaluated for contamination and receive certification (an agreement between the developer and the state) that if the property is cleaned up according to the state program, it will not be subject to scrutiny by the state of Illinois. The study finds that the combined effect of entry and certification is small -- about 1% -- but significant, with an elasticity of 0.03 on property value, compared to an otherwise identical property that has not entered the program or been certified. The results were localized to a distance of approximately two city blocks from the brownfield.

Like Linn, we look at the effects of a state program – the NC Brownfields Program – on residential property values. Our study focuses on two similar variables: constructive notice and brownfield remediation. Constructive notice corresponds to the date when a developer applies to enter the NC Brownfields Program, signaling its intention to remediate and redevelop the property. Constructive notice is a legal term used to refer to notice that is implied due to the information being a part of a public record and which a reasonable person could have been aware of, even if notice was not delivered personally. Remediation refers to one of three conditions: no contamination is found when the site is assessed; land use restrictions, with or without engineering barriers, have been established to prevent contamination from reaching the public; or the site has been cleaned up, typically requiring the removal of contaminated soil. Linn indicates he did not have data on remediation, so he used certification instead as it demonstrates a clear intent to remediate and redevelop a brownfield site.

A second key difference is that Linn does not have data on the effect of unremediated brownfields on property values. So in his study, it is not possible to say how the effects of entry and certification compare to the initial effect of the brownfield. Our study considers both the effect of the brownfield and constructive notice and remediation.[12]

In sum, most studies of hazardous waste sites tend to show that the presence of a site depresses property values, and site cleanup and redevelopment increases property values. But in several cases, the effects are small, and even zero. In order to determine the benefits of brownfields programs, it is necessary to estimate the depressing effect of brownfields on property values, if any, and the stimulating effects of the different steps taken in their rehabilitation and redevelopment.

[12] Linn; Noonan, Krupka and Baden; Noonan and Krupka (2007); and Hanna (2007) attempt to correct for estimation problems such as endogeneity and reverse causation. We note these issues in section 4, where we discuss our results.

3. Model, Data, and Hypotheses

This study uses the hedonic approach to determine the effects on sales prices using residential property sales[13] in Charlotte, NC of nearby brownfields, anticipated remediation of those brownfields as signaled by constructive notice -- a developer applies to the NC Brownfields program to have the brownfield property assessed -- and brownfield remediation. To estimate the effects of proximity to a brownfield, we consider the distance (and distance squared) of the property from the nearest brownfield. We also consider the size of the nearest brownfield as well as brownfield density, as defined by the number of brownfields within the same census tract as the property.[14] Constructive notice is a binary variable that equals 1 if a sale occurs after the date where a developer has applied to the brownfields program, which we take as an indication of the intent to remediate and ultimately redevelop the property.[15] Remediation equals 1 if a sale occurs after the date when remediation has been completed.

The sample used in this analysis was taken from Polaris, a publically available database of property characteristics and sales information maintained by the City of Charlotte and Mecklenburg County Government Services and Information Office (City of Charlotte, 2013). The original dataset included information about sales from 1991 to 2005 and property assessments from 1991, 1998, and 2003 (NC law requires at least one assessment every eight years). The sample selected for study only uses residential sales between 1997 and 2005 to align with the start of the NC Brownfields Program. We focus on sales rather than assessment values,

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[13] The residential properties include single family detached houses.

[14] The bfdensity parameter is omitted throughout the regressions. The reason is because we use fixed effects on census tracts while the bfdensity parameter is solely based on census tracts.

[15] Linn includes lags between the time of developer certification and when it affects property sales.We also account for it by the dummies for con_notice and bf_remediated, which equal 1 only if the house sold after constructive notice was given or after remediation was given.

as do most hedonic studies, as they better reflect market values.[16] The sales prices were indexed to 1995 using information from the Office of Federal Housing Enterprise Oversight (OFHEO, 2007).

A series of filters were applied to remove observations that had missing data or were duplicate observations. Outliers such as indexed sales prices greater than $2.0M and lot sizes greater than 600,000 sqft (13.8 acres) were also removed. The final sample contains information for 18,109 individual sales of residential properties between 1997 and 2005.

We examine the effects of brownfields and their remediation at three stages: the effect of brownfields on property value prior to constructive notice and any remediation of the site; the effect of constructive notice, but not remediation, prior to sale; and the effect if the site is remediated prior to sale. At the second stage, "notice" equals 1 when a sale occurs after the date of developer notice. At the third stage, remediation equals 1 for any sales that occur after remediation. The specific hypotheses are:

> *Hypothesis 1:* Prior to notice that a developer intends to remediate and redevelop the brownfield, the sales price will be lower than for an otherwise comparable house that is not located near an undeveloped brownfield.
>
> *Hypothesis 2:* Post constructive notice, but prior to remediation, the sales price will be higher, all other things being equal, than when there is no notice at the time of the sale.
>
> *Hypothesis 3*: Post remediation, the sales price will be higher for a house proximate to a remediated brownfield than one near a brownfield that has not been remediated, all other things being equal.

In order to test these hypotheses, we use a hedonic model of the form:

$$P_i = \beta_0 + \beta_1 D_i + \beta_2 \sum_{i=1}^{n} H_i + \beta_3 \sum_{j=1}^{J} N_j + \beta_4 \sum_{k=1}^{K} BF_{k,} + e_i$$

[16] In fact, property owners successfully challenged the most recent Mecklenburg county assessment, which is having to be redone.

The dependent variable, P_i, is the logged value of the indexed sales price for house i (realprice).[17] The independent variable, D_i is the distance from the nearest brownfield (bfdist), measured in feet, calculated using the XY coordinates of the centers of the parcels mapped in GIS. To allow for non-linearity, we also include distance squared (bfdist2). H_i is a vector of house characteristics including age at the time of the sale (age), the number of full bathrooms (bathrooms) and bedrooms (bedrooms), the size of the lot (lotsize, measured in sqft), and whether the house has air conditioning (ac=1 if it has air conditioning and 0 otherwise).[18] The census tract in which the house is located is used for the neighborhood characteristics for each house, N_i.

The brownfield characteristics (BF_K) include the number of brownfields within the same census tract as the residential property (bfdensity); the size of the brownfields (bfdsize); and constructive notice (con_notice). A variable for the interaction between notice and size (bfdsize*notice) is also included.[19], [20] The remediation variable indicates whether the brownfield was remediated during or before the year the house sold (bfd _remediated).[21]

Table 1 provides summary statistics for the variables included in estimation.

(Table 1 goes here)

House prices range from \$316 to \$1.45M with a mean of \$126,600 and a median of \$95,200. We dropped observations having non-indexed prices less than \$10,000. The age of the residential

[17] Hedonic studies typically use the log of price.
[18] We do not have information on whether or not the house has central air conditioning.
[19] We also interacted distance with brownfield variables. The interaction terms are generally insignificant, and have little effect on the results.
[20] Linn (2012) focused on a similar program offered by the Illinois state government but uses the year that the agreement was signed (or certified in Linn's terminology). We use the application date as the majority of signed agreements in the North Carolina program came after 2005.
[21] We have separate data on each of these three cases, but decided that for our purposes of focusing on remediation, we would not distinguish between the three. The three are mutually exclusive, and any of the three implies that the brownfield has been remediated.

properties at the time of sale had a range of 0 to 129 years with a mean of 32 and a median of 33, reflecting Charlotte's growth since the 1950s. The minimum lot size (1070 sqft) represents parcels upon which are located condominiums and townhouses. The mean lot size is 13,300 sqft and the median is 11,200 sqft (roughly one-third and one-quarter of an acre respectively). In the sample, 82% of the properties had some form of installed air conditioning (excluding removable window units). The size of the brownfields range from 5640 sqft (one-eighth of an acre) to over 5 million sqft (about 119 acres), with a mean of 878,000 sqft and a median of 262,000 sqft (6 acres).[22] Regarding the notice and remediation variables, 41% of the properties (about 7163 observations) sold after the developer signaled its intention to remediate and redevelop the associated brownfield while 15% of the properties (about 2626 observations) sold after the brownfield had been remediated. We chose to use the median rather than the mean values when calculating the economic effects, given the skewness of most of the variable distributions.

The length of our study period, nine years, could result in changes in housing characteristics that confound our final results if left undiscovered and unaccounted for. We guarded against this possibility by dividing our study period into three sub-periods, each three years long, and examined the housing characteristics during each period. The details of this examination are in Appendix 1. Briefly, the only housing characteristic that changed significantly over time was the median and mean value for the age of house sold. upon investigation, this discrepancy was due to a late entrant into the Brownfield Program that was surrounded by housing, a significant proportion of which was over 50 years old including a grouping of houses over 70 years old and a few houses over 100 years old.

[22] The maximum size is an outlier (the next largest is 1.1 million sqft or 25.6 acres). However the brownfield is in a central location within Charlotte and we did not believe we should remove it. We ran the analyses both with and without the brownfield and the results were similar.

We also attempted to discover any occurrences of gentrification and reverse causality, both of which could potentially bias our estimates. The potential for these events to inflate the estimated effects of brownfield revitalization have been acknowledged and discussed by others (Kaufman and Cloutier, 2005 and Linn, 2013). In his study, Linn attempted to control for gentrification by using the median pre-study house prices interacted with year fixed effects. Our data has too few observations, especially at the shorter distances, to include such a control. Instead, we did a graphical analysis to identify any changes in housing prices over time for each census tract that might signal gentrification of an area. To account for reverse causality, we used our knowledge of local development patterns over the study time period to identify the most likely areas in which rising housing prices may have enticed a potential developer into revitalizing a nearby brownfield rather than the revitalization of said brownfield encouraging house prices to rise. The details of both analyses are in Appendix 2. With one exception, any potentially confounding events were limited to at most a 1-percentage point change in our explanatory variables of interest; the exception showed a possible difference of 6 percent, although the direction was actually opposite of what would be expected if there were reverse causality. So reverse causality does not appear to be causing an upward bias in the baseline results when all brownfields are included.

The analysis uses OLS with fixed effects (census tracts) and accounting for clustering within tracts. Year dummy variables for 1997 to 2004 accounted for time effects. We performed the regressions at varying distances of 0.3, 0.5, 0.75, 1, 1.5, and 2 miles.[23] The analyses were done with cumulative distances (the observations accumulated as the distance expanded) and

[23] We did not have sufficient observations to do the analysis at 0.25 mile, the closest distance used in Linn. As will be seen, the sample size at 0.3 miles is still relatively small, as shown by the lack of significance for some of the house characteristics.

discrete distances (the observations were segregated into concentric rings) using the same distances as the boundaries. The variables bfdist and bfdist^2 were divided by 1,000 and the variables lotsize and bfdsize were divided by 10,000 for convenience in interpreting the regression coefficients. We report significance levels of 10%, 5%, and 1%.

4. Results and Discussion

Tables 2 and 3 show the complete set of coefficient estimates for the hedonic model. Table 2 shows results grouped by residential properties within a given distance from the brownfield, beginning with 117 houses within 0.3 miles of the nearest brownfield, to the entire sample of 18,109 houses, all of which are within 2 miles of the nearest brownfield. Table 3 uses discrete distances, rather than continuous distances, such as 0-0.3 and 0.3-0.5 miles rather than 0-0.5 miles.

(Tables 2 and 3 go here)

The reason for considering discrete distances is to examine whether results that might be attributed to houses up to 0.5 miles away might really be attributable to effects that extend only up to 0.3 miles. Similarly, if we obtain significant results for the entire sample of houses, we need to know whether those results really reflect brownfield effects out to that distance. The discrete interval of 1.5-2 miles shows whether or not brownfield effects extend out that far. We note that the hedonic variables for house characteristics – age of home at time of sale (age), bathrooms, bedrooms, lot size, and the presence of air conditioning -- all have the expected coefficients, with statistical significance generally increasing with larger sample sizes. The effects of the hedonic variables, such as house characteristics, should not be dependent on distance from the brownfield, so the need to examine discrete as well as continuous distances is motivated strictly by the examination of the brownfield variables.

We now turn to the brownfield-related variables. We begin with distance from the brownfield, which, along with distance squared, has been the most commonly employed method of observing the effects of contaminated properties such as brownfields. Referring to table 2 results using continuous distances, the coefficient of distance is statistically significant only at 0.75 mile. However, it does not have the expected sign (the negative sign suggests that property sales prices decrease with increasing distance from a brownfield, opposite of expectations). Looking at the discrete distances in table 3, there are no significant coefficients for brownfield distance. While the theory underlying hedonic studies leads to the expectation of property value increasing at a decreasing rate with distance from a brownfield, there have been a number of studies where the distance variable has been insignificant. Most notably, Greenstone and Gallagher found no significant difference in property value changes when comparing two sets of properties with similar amounts of contamination, where only one set was eligible for Superfund cleanup. If their widely cited study of Superfund sites did not discern a difference, it is even more likely that it will be hard to discern a difference for brownfields, which are less contaminated than the sites examined by Greenstone and Gallagher.

While distance in feet to the nearest brownfield (bfdist) was statistically significant in only one of the regressions (and then only at a 10% level), other brownfield characteristics showed significant results over a greater number of runs. We examine brownfield size, constructive notice, and remediation, which respectively indicate the three stages of our hypotheses: brownfield effect prior to notice or remediation, brownfield effect after notice but prior to remediation, brownfield effect after remediation.

Brownfield size reduces property values up to one mile from the nearest brownfield, with coefficients significant at the 1% level. Beyond one mile, the magnitude is much smaller and the coefficient is no longer significant.[24] The result is consistent with the expectation that a larger brownfield would detract more than a smaller brownfield. Both the continuous and discrete distance measures show the same result that the effect extends out to one mile from the nearest brownfield.

Constructive notice enhances property values along the full 2 mile distance for both the continuous and discrete measures, with the exception of the coefficient for the 0.5-0.75 mile ring. The results are relatively consistent using both the continuous and discrete distance measures. We would expect notice that a developer seeks to remediate and eventually redevelop a brownfield to enhance property values. Magnitude drops off rapidly beyond 0.5 miles. The coefficient for the interaction term between notice and brownfield size is negative and significant up to 0.5 miles in both tables. Thus, constructive notice lifts property values, but less so for larger brownfields. We are agnostic regarding the sign of the interaction coefficient. On the one hand, the sign is mildly surprising, as it would seem that given the depressing effect on property values of a large brownfield, the amount of recovery in property value from developer interest would be larger. Another interpretation, though, says that once a person interested in a particular party becomes aware of a nearby brownfield (represented by *con_notice*), the size of the brownfield may depress property values.

The last stage is that of remediation, which we expect to have a positive effect. The results generally show a positive but diminishing effect on property values up to 2 miles. The

[24] We use STATA to run the regressions. At 0.3 miles, STATA omitted this variable. Upon examining the data, there are only four housing areas accounting for almost the entire 117 properties sold within 0.3 miles of a brownfield. This limited variation resulted in multicollinearity. STATA also omitted our variable for brownfield density, a count of the number of brownfields within the brownfield census tract. But the results beyond 0.3 miles are clear.

discrete results show significant results out to 0.5 miles. There is a perplexing sign reversal for properties within 0.3 miles of the nearest brownfield. Corona reported a similar finding, and suggested that nearby residents could anticipate construction and traffic, although his evidence did not support the hypothesis, while Linn (2012) suggests the possibility of a negative effect for the closest properties. Looking outside the brownfields literature, other researchers discuss the negative effect of "visual disamenities" on property values within a short distance of the structure or property upon which the visual disamenity is located (Krueger, Parsons & Firestone (2011), offshore wind farm; Filippova & Rehm (2011), cell phone towers; Lee & Li (2009), subdivision water detention basin design). Our results at 0.3 miles could be identifying the negative effect of having a nearby visual disamenity such as an empty building or lot.

To gain some understanding of the policy implications of these findings, we approximate the effects based on median values from table 1. The median brownfield size from table 1 is nearly 262,000 sqft (which becomes 26.2 in the calculations). Based on tables 2 and 3, a 10,000 square foot increase in the size of a brownfield results in a decrease in property value of about 3%.[25] For an otherwise comparable house valued at the median of $95,000 (adjusted using a 1995 price index), the house near the brownfield loses almost $3000 in value for each 10,000 square foot increase in the size of the brownfield.[26]

If stage 2 is reached where a developer applies for constructive notice, as is the case for about 40% of the transactions in this sample, a house within 0.5 miles from the brownfield experiences an increase in value, with the size of the increase decreasing with the size of the brownfield. For the median size brownfield of 262,000 sq. ft., the net effect is on the order of 0.3 – 26.2*(0.005) = 0.17 or 17%. The $95,000 median house would now be worth $111,000 given

[25] Recall that the dependent variable is the log of price.
[26] We are assuming the effect is linear. It is likely that in reality, the effect diminishes with increasing distance, an effect that could be captured by including the square of brownfield distance.

the developer intentions, a gain of almost $16,000. For our data sample of approximately 500 houses within 0.5 miles of a given brownfield and based on median values, 200 homes (40% of 500) will gain the premium for an overall gain of around $3,230,000. We attribute these benefits to the market expectation that a developer applying to the brownfields program expects to remediate and eventually redevelop.

The benefits of the brownfields program increase further where there is actual remediation (and would increase again with redevelopment). Again choosing the 0.5 mile distance, the lift to property value is a little over 10% (bearing in mind that homeowners out to 2 miles will benefit, and homeowners within 0.3 miles are actually worse off). The house that had already appreciated by almost $16,000 would now add approximately $11,000 to $122,300. Approximately 15% of sales took place after remediation. For the sample of 500 houses within a 0.5 mile of the nearest brownfield, there is an additional $10,000 in benefits for the 75 homes that sell after remediation, or an additional $830,000, bringing the overall gain to $4.1 million. The eventual gain will likely be larger, as a longer time period would allow more developers to remediate (and then a fourth stage of benefits when they redevelop).

These results are larger than those found in similar studies (Linn, 2012, Kaufman and Cloutier 2005). One possible explanation is that Charlotte's brownfields are mildly contaminated as compared to cities more dependent on heavy industry. So brownfields in our sample have less of a detrimental effect, and there may be a higher premium for developer notice given the greater likelihood that contamination will be mild, making it more likely that remediation and redevelopment will occur. Another possibility is that we have not completely accounted for two sources of upward bias given by Linn (2013). First, Linn suggests the (dis)amenity effect. Houses near brownfields tend to be in industrial areas with lower quality amenities (e.g. lowquality schools). So the reduction in property values attributed to brownfields is biased upward, because part of the reduction is due to lower amenities, if those amenities are not captured by variables for neighborhood characteristics. We include census tracts, but their inclusion may not do as good of a job of accounting for (dis) amenities as Linn's block measure, which is considerably smaller than a census tract. He also interacts his block measure with other variables, but we are unable to do so given our much smaller sample size, as compared to Linn. The second bias is the possibility of reverse causality. We may be attributing too much of the increase in property values to developer actions. The increase in property values may be exogenous to some degree, and the developer response to those rising values endogenous. Linn suggests including a pre-sample median house price interacted with a time trend as a way to counter this simultaneity. Again, our smaller sample size limited our ability to add a large number of additional variables. Instead, we use knowledge of Charlotte's development trends to isolate certain potentially problematic brownfields and tested the sensitivity of our results with and without these brownfields, as discussed in Appendix 2.

5. Summary and Conclusions

We perform a hedonic study of the effects of brownfields on residential properties in the new south city of Charlotte using data from 1997 through 2005. Charlotte does not have a legacy of heavy industry, and so its brownfields are likely to be less contaminated than those in other studies of cities with a history of heavy industrial contamination. Lesser contamination allows for easier remediation and redevelopment, but also increases the chance that the private sector will do the remediation and redevelopment with less assistance from the government than in cases of more serious contamination.

One common characteristic of studies of brownfield and Superfund effects is the inclusion of distance as a measure of the effect. The expectation is that property values increase at a decreasing rate with distance from a brownfield. Thus, it has been somewhat of a surprise that some studies have not found this effect, with distance being insignificantly different from zero. Greenstone and Gallagher (2008) obtained Superfund inclusion, and found no difference in property value changes between those properties that were ultimately placed on the Superfund list, and those that were not. Our study joins this minority finding; distance is rarely statistically significant for any of the distance measures.

Examining other brownfield-related variables as well as looking for brownfield effects at different distances from the brownfield, we do find effects, and that distance matters. Our distance design is inspired by Linn (2013), who performs separate analysis from houses within varying distances of a brownfield. As in his study, the evidence supports brownfield effects, but generally extending up to one mile, whereas he found a more limited impact of 0.25 miles. We include variables for the size of the brownfield, constructive notice for which a developer has applied to obtain a liability protection guarantee from the state in return for remediating and redeveloping the site, and for sites that have been remediated. We note that we do not have adequate data for examining redevelopment. We attempted to include brownfield density, but our measure of counting the number of brownfields within the same census tract of a house was omitted due to multicollinearity.

For the most part, we find the expected signs for each of these variables, at least up to one mile of the brownfield and sometimes beyond. As the brownfield increases in size, property value falls. Constructive notice boosts value, although the increase is smaller as brownfield size increases. Remediation — active cleaning of the property, finding no contamination upon assessment, or restricting use with or without engineered barriers -- adds further to property value, although its magnitude appears to be smaller than that of constructive notice. It may well be that constructive notice reflects a degree of anticipated remediation. Constructive notice also tends to have a higher level of statistical significance than does remediation.

We provide an estimate of the benefits of the NC Brownfields program for Charlotte for the residences in the sample on the order of $4 million. Such benefit estimates are needed to evaluate the extent to which governments should go beyond market forces in influencing developers to remediate and redevelop these sites. To the extent that brownfields programs have other motivations, such as environmental justice motivations of targeting lower-income neighborhoods that may bear a disproportionate burden of the brownfields legacy, we cannot directly contribute to the equity debate. But at least part of the motivation should include efficiency considerations, such as effects on property values.

Areas of future study include updating the information to include more recent years to more fully capture the effects of certification (signing the Brownfields Agreement), remediation, and property development on sales prices of nearby residential properties. Another path of investigation is the use of property assessment data that may allow us to use a difference in difference method as we will have multiple observations for the same house over several assessment years.[27] Using additional information about specific brownfields and neighborhoods may help refine our model and provide better estimates of the benefits of identifying, remediating, and redeveloping brownfield properties. Finally, using existing and updated information we can explore the issue of simultaneity between residential sales prices and redevelopment plans.

[27] We have relatively few repeat sales, so we cannot use a difference-in-differences approach with our sales data. And as mentioned in an earlier footnote, we have concerns about assessment values in general, and Charlotte in particular.

Before public programs allocating funds to brownfield revitalization projects (i.e., remediation and redevelopment) are implemented, the benefits of the projects should be compared to the costs incurred by the program. Several previous studies have estimated the benefits of remediation and redevelopment projects in urban areas that lack the capability to grow geographically and that have histories of heavy (more contaminating) industry. Few studies have looked at the benefits of brownfield remediation projects—such as an increase in nearby property values—in cities such as Charlotte that have a history of light industry (less contamination) and have extensive geographic growth potential. Our results suggest that programs that limit future potential developer liability in return for remediation to an agreed-to level benefit the public in the form of rising values for nearby residential properties even in a New South city and, thus, may be appropriate targets for public funding.

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Table 1. Descriptive Statistics (at 2 Miles)

Variables	***N***	***Median***	***Mean***	***Std. Dev.***	***Min.***	***Max.***
realprice ($)	18109	94,883	127,238	132,072	1,046	1,967,515
bfdist (1000s ft)	18109	8.32	7.81	2.19	0.25	10.56
bfdist^2	18109	69.18	65.79	30.32	0.06	111.51
age (yrs)	18109	32	31.01	26.74	0	129
age^2	18109	1,024	1,676.60	2,037.67	0	16,641
fullbaths	18109	2	1.75	0.67	1	7
bedrooms	18109	3	3.10	0.69	1	9
lotsize (10000s sqft)	18109	1.12	1.34	1.33	0.11	49.03
ac (1=has AC, 0 otherwise)	18109	1	0.82	0.38	0	1
bfdensity	18109	1	1.07	0.42	1	5
bfsize (10000s sqft)	18109	26.19	86.20	155.35	0.56	517.30
con_notice (1=yes, if house sold after application filed, 0 otherwise)	18109	0	0.41	0.49	0	1
*bfsize*con_notice*	18109	0	20.74	78.14	0	517.30
bfd_remediated (1=yes if house sold after remediation, 0 otherwise)	18109	0	0.15	0.36	0	1

Table 2. Effects of Brownfield and Hedonic Variables on Property Values: Cumulative Distances

Variables	0.3 mile	0.5 mile	0.75 mile	1 mile	1.5 miles	2 miles
bfdist	-0.31041	-0.04550	-0.25698	-0.00563	0.03979	0.04128
	(0.98)	(0.20)	(1.81)+	(0.05)	(0.63)	(1.04)
bfdist^2	0.19858	0.00292	0.04706	0.00221	-0.00108	-0.00107
	(0.91)	(0.05)	(2.16)*	(0.11)	(0.22)	(0.41)
age	-0.02686	-0.01504	-0.00690	-0.00583	-0.00921	-0.01010
	(3.95)**	(2.05)+	(2.31)*	(1.58)	(4.42)**	(5.71)**
age^2	0.00041	0.00016	0.00007	0.00005	0.00007	0.00010
	(3.48)*	(1.57)	(1.87)+	(1.10)	(2.89)**	(4.95)**
fullbaths	0.16405	0.08972	0.09420	0.14815	0.13721	0.15679
	(21.40)**	(3.11)**	(2.70)*	(4.81)**	(6.47)**	(13.83)**
bedrooms	0.02281	0.06788	0.12973	0.16747	0.14448	0.15102
	(1.03)	(1.42)	(2.92)**	(6.20)**	(10.99)**	(13.86)**
lotsize	0.04054	0.04443	0.02908	0.03545	0.04374	0.03883
	(1.72)	(2.16)+	(2.46)*	(5.78)**	(5.79)**	(4.94)**
ac	0.26731	0.14725	0.15348	0.13635	0.11623	0.13022
	(20.66)**	(2.52)*	(3.78)**	(4.20)**	(6.26)**	(7.87)**
o.bfdensity	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
bfdsize	omitted	**-0.02546**	**-0.02477**	**-0.02904**	-0.00038	-0.00008
	-------	(6.22)**	(3.24)**	(6.04)**	(0.43)	(0.14)
con_notice	**0.32663**	**0.26969**	**0.08660**	**0.11587**	**0.08367**	**0.06014**
	(1.91)+	(2.70)*	(2.02)+	(2.12)*	(3.42)**	(3.17)**
bfsize*notice	**-0.00345**	**-0.00500**	-0.00117	-0.00023	-0.00001	0.00008
	(2.45)*	(5.20)**	(1.40)	(1.14)	(0.11)	(1.08)
bfremediated	**-0.17130**	**0.11855**	**0.08316**	0.05885	**0.05904**	**0.04971**
	(1.97)+	(1.88)+	(2.15)*	(1.65)	(2.27)*	(1.95)+
_Iyear_1997	0.07206	-0.12434	-0.13757	-0.04115	0.04168	0.02098
	(0.21)	(1.07)	(1.14)	(0.41)	(0.75)	(0.45)
_Iyear_1998	0.00126	-0.19853	-0.09240	0.06016	0.06113	0.04069
	(0.01)	(1.27)	(1.01)	(0.67)	(1.34)	(1.03)
_Iyear_1999	0.09000	-0.06013	0.00912	0.06160	0.07310	0.06868
	(0.36)	(0.43)	(0.10)	(0.73)	(1.70)+	(1.88)+
_Iyear_2000	0.14103	-0.05029	0.01465	0.16051	0.10831	0.09474
	(0.50)	(0.62)	(0.16)	(2.08)*	(2.91)**	(3.03)**
_Iyear_2001	0.01918	-0.00846	0.02683	0.13205	0.09533	0.06870
	(0.09)	(0.11)	(0.43)	(2.23)*	(2.98)**	(2.43)*
_Iyear_2002	0.05104	0.08271	0.08609	0.09012	0.08833	0.07584
	(0.25)	(1.40)	(1.16)	(1.37)	(2.82)**	(2.53)*
_Iyear_2003	-0.13587	0.09957	0.04781	0.04526	0.05659	0.05587
	(1.10)	(1.64)	(0.88)	(1.07)	(2.13)*	(2.48)*
_Iyear_2004	-0.07518	0.01378	0.00086	0.02272	0.01372	0.01830
	(0.44)	(0.21)	(0.01)	(0.52)	(0.56)	(1.05)
_cons	10.82983	12.25951	11.71758	11.53129	10.43614	10.37459
	(27.57)**	(33.44)**	(32.15)**	(40.12)**	(43.04)**	(61.65)**
R^2	0.38	0.21	0.17	0.18	0.17	0.20
N	117	497	1,397	2,597	7,812	18,109

+$p<0.1$; * $p<0.05$; ** $p<0.01$

Table 3. Effects of Brownfield and Hedonic Variables on Property Values: Discrete Distances

Variables	0-0.3 mile	0.3-0.5 mile	0.5-0.75 mile	.75-1 mile	1-1.5 miles	1.5-2 miles
bfdist	-0.31041	1.56209	0.64182	0.28707	-0.29416	0.33447
	(0.98)	(1.19)	(0.73)	(0.27)	(1.43)	(1.24)
bfdist^2	0.19858	-0.37031	-0.07376	-0.03715	0.02247	-0.01692
	(0.91)	(1.14)	(0.57)	(0.33)	(1.45)	(1.17)
age	-0.02686	-0.01174	-0.00044	-0.00631	-0.01187	-0.01253
	(3.95)**	(1.28)	(0.08)	(1.15)	(5.24)**	(6.17)**
age^2	0.00041	0.00011	0.00000	0.00005	0.00009	0.00014
	(3.48)*	(1.00)	(0.04)	(0.77)	(3.82)**	(6.48)**
fullbaths	0.16405	0.07371	0.09021	0.21995	0.12040	0.15772
	(21.40)**	(2.02)+	(2.09)*	(5.39)**	(4.61)**	(10.15)**
bedrooms	0.02281	0.06626	0.18256	0.16923	0.12532	0.15174
	(1.03)	(0.90)	(5.07)**	(4.04)**	(10.21)**	(9.95)**
lotsize	0.04054	0.03388	0.02895	0.03528	0.04758	0.03547
	(1.72)	(1.06)	(3.09)**	(4.40)**	(4.56)**	(3.78)**
ac	0.26731	0.14029	0.16249	0.10778	0.10590	0.12804
	(20.66)**	(1.74)	(3.64)**	(2.87)**	(4.75)**	(5.60)**
o.bfdensity	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
bfdsize	omitted	**-0.02980**	**-0.02951**	**-0.03189**	0.00033	0.00017
	---------	(6.65)**	(3.02)**	(3.93)**	(0.68)	(0.26)
con_notice	**0.32663**	**0.26640**	0.08406	**0.16726**	**0.06147**	**0.04206**
	(1.91)+	(2.50)*	(1.22)	(1.75)+	(1.95)+	(1.74)+
bfsize*notice	**-0.00345**	**-0.00535**	0.00094	-0.00024	0.00009	0.00014
	(2.45)*	(4.26)**	(0.64)	(1.34)	(1.25)	(1.40)
bfremediated	**-0.17130**	**0.12781**	0.08511	0.03690	0.06165	0.04037
	(1.97)+	(1.90)+	(1.46)	(0.48)	(1.65)	(1.25)
_Iyear_1997	0.07206	-0.20077	-0.09485	0.01693	0.05262	0.01082
	(0.21)	(1.72)	(0.65)	(0.12)	(1.04)	(0.20)
_Iyear_1998	0.00126	-0.35963	-0.00021	0.16465	0.06196	0.02827
	(0.01)	(1.91)+	(0.00)	(1.56)	(1.38)	(0.60)
_Iyear_1999	0.09000	-0.10835	0.07330	0.08021	0.09871	0.05916
	(0.36)	(0.79)	(0.68)	(0.65)	(2.15)*	(1.29)
_Iyear_2000	0.14103	-0.10307	0.10843	0.24189	0.08727	0.07665
	(0.50)	(1.12)	(1.06)	(2.38)*	(2.06)*	(2.03)*
_Iyear_2001	0.01918	-0.09882	0.07638	0.18846	0.08037	0.04616
	(0.09)	(0.78)	(1.01)	(2.15)*	(1.97)+	(1.19)
_Iyear_2002	0.05104	0.04716	0.06901	0.09554	0.09925	0.06679
	(0.25)	(1.22)	(0.73)	(0.93)	(2.52)*	(1.71)+
_Iyear_2003	-0.13587	0.07613	0.02996	0.02195	0.07003	0.04967
	(1.10)	(1.29)	(0.43)	(0.34)	(2.63)*	(1.65)
_Iyear_2004	-0.07518	0.04237	-0.02868	0.03007	0.02256	0.02151
	(0.44)	(0.90)	(0.54)	(0.60)	(0.95)	(0.96)
_cons	10.82983	10.78864	9.67497	11.33374	11.70533	9.05581
	(27.57)**	(7.79)**	(6.38)**	(4.38)**	(17.15)**	(7.19)**
R^2	0.38	0.21	0.18	0.23	0.16	0.22
N	117	380	900	1,200	5,215	10,297

+ p<0.1; * p<0.05; ** p<0.01

Appendix 1
Analyzing Sub-Period House Price Growth Trends

This study uses house sales data from 1997 to 2005 or nine years of data. During that time, different housing and brownfield characteristics may change. If left unobserved and unaccounted for, these changes in parameter values could bias the coefficients of the explanatory variables of interest, especially the parameter *con_notice*, which identifies when those interested in a particular property may become aware of a near-by brownfield site.

Econometric techniques exist to control for such changes in characteristics and sales prices over time. However, due to the limited size of our data set, especially when attempting to estimate the local (less than one-half mile) effects, these techniques are not available. Instead, we chose to follow a method used by Linn (2013) and divide the time period into sub-periods and examine the changes seen in the values of the parameters used in our statistical analysis, especially changes in sales prices and house characteristics. The full time period is nine years (1997 to 2005) and each sub-period is three years. Table A.1 shows the values for the full period and each sub-period.

The parameter values are generally stable across the time sub-periods and correspond with the values for the full time period, except for *age*, which will be discussed in detail later. The indexed sales prices over the entire city increase by about $4000 over each subsequent sub-period. The values for *age* are stable for the first two time sub-periods (1997-1999 and 2000-2002) but rise abruptly for the final sub-period (2003-20005). The values for *con_notice* and *bfd_remediated* both increase over time, which indicates that more brownfields were entering the NC Brownfields Program and being remediated (cleaned, finding no contamination, or instituting land use restrictions) over time. These increases are expected and suggest that potential developers recognized the value of the program after the first-movers successfully navigated the process.

Table A.1. Descriptive Statistics for Full and Sub-Time Periods

	Hedonic Parameter Means for Select Sub-Periods			
Variables	1997-2005	1997-1999	2000-2002	2003-2005
realprice ($)	127,238	122,004	126,284	130,526
bfdist (1000s ft)	7.81	7.90	7.83	7.75
age (yrs)	31.01	26.27	26.68	36.38
fullbaths	1.75	1.77	1.79	1.72
bedrooms	3.10	3.16	3.12	3.06
lotsize (10,000s sqft)	1.34	1.39	1.31	1.33
ac (1=has AC, 0 otherwise)	0.82	0.84	0.85	0.79
bfdensity	1.07	1.09	1.05	1.08
bfdsize (10,000 sqft)	86.20	83.62	81.88	90.47
con_notice (1=yes, if house sold after application filed, 0 otherwise)	0.41	0.04	0.14	0.78
bfd_remediated (1=yes if house sold after remediation, 0 otherwise)	0.15	0.00	0.04	0.31
Number of observations	18109	4150	5699	8260

The parameter *age* showed a surprising increase of about 9 years (from 27 years to 36 years) for the sub-period 2003-2005, as compared to the other sub-periods which had stable mean values. Further examination found that the mean number of bedrooms and the mean proportion of houses with installed air conditioning showed decreases in the same sub-period. These are evidence of a substantial increase in older, smaller, homes being sold in the three-year period, which could suggest an extensive gentrification event or developers buying these older homes to create a new subdivision.[28] However, there is no corresponding change in the increase in sales prices which would be expected if significant gentrification occurred.

Examining the data revealed that the rise in mean age in the final time sub-period was caused by the entry of a single brownfield site into the program in 2003. The site was the nearest brownfield to over 1400 properties (none closer than a mile), all of which were older houses, a legacy of when Charlotte had several textile mills along the corridor in which the brownfield site is located. A closer look at the age of houses indicates that over 40% are older than 50 years, 22% are older than 60 years, and nearly 10% are older than 75 years (the oldest being 105 years). These findings also explain the decrease in number of bedrooms and number of houses with installed air conditioning.

Identifying the driver of the change in mean age combined with the knowledge that the closest property sale to the brownfield site was at least a mile distant leads us to conclude that little if any gentrification occurred during our study time period (1997-2005). However, our study only considers single family residences and much of the "gentrification" occurring in areas such as the one discussed above involve the renovation of the mills and other industrial buildings into condominiums and apartments. Hence, this study may not be capturing the full effects of either brownfield redevelopment or gentrification.

[28] Developers buy several contiguous properties, demolish the older structures and build new housing on the cleared land.

Appendix 2
Testing for Reverse Causality

Assessing, cleaning, and redeveloping a brownfield is potentially costly, depending on the type and amount of contamination found on the property. Thus, a potential developer of a brownfield property must consider the surrounding area, its current socio-economic condition, and any expected future changes in the socio-economic condition of the area if the redevelopment occurs. Most brownfield models assume that the developer sees the future growth of an area, decides to redevelopment a brownfield within or in proximity to that area, and property values increase due to this foresighted decision. However, it is also likely that a potential developer, witnessing the economic growth of a neighborhood, is enticed to redevelop a brownfield site within or next to that neighborhood, recognizing that the economic growth means a larger customer base. Thus, the question of reserve causality must be acknowledged and, if possible, controlled for in hedonic studies of brownfields revitalization. Kaufman and Cloutier (2005) recognized that problem of reverse causality while Linn (2013) tried several statistical techniques to control for it. While some of his efforts are appealing, we are limited by the size of our data set to try other methods.

In this appendix, we use our knowledge of development trends in Charlotte over the study period to identify probable areas in which rising property values led a developer to enter the NC Brownfield Program, rather than the standard belief that a developer entering the program (represented in our model by variable *con_notice*) results in increased property values. The specific hypothesis we are testing is:

In situations where reverse causality—rising property values enticing a developer to enter the NC Brownfields Program—exists, the variable representing developer entry (con_notice) will have a larger coefficient when the brownfield is in the analysis than when it is not.

The upward bias of the coefficient is due to the exaggerated influence developer entry is given when property values were already rising before the developer signaled its intention to revitalize a near-by brownfield. Therefore, we test the sensitivity of our overall results to possible reverse causality by removing select brownfields from the dataset and rerun our regression analysis. If the coefficient for *con_notice* is demonstrably higher in the overall regression compared to the restricted dataset then we may have identified an area in which property values were rising before and independent of developer entry into the Brownfields Program.

Based on knowledge of where property values had risen, we selected two brownfields to test. Both brownfields are located within historic neighborhoods near the central business district. The Worthington brownfield is surrounded by the Wilmore neighborhood that has a mix of industrial, commercial and residential properties and was preferred by the young professionals who flocked to that area. The Elizabeth brownfield is on the edge of the Elizabeth neighborhood that has houses on large, mature lots which attract executives with families.[29] The attractiveness of the areas within the influence of these brownfields is evident in the number of houses sold during the study period, especially the latter half when banking and financial services became Charlotte's dominant industry. Figure A.1 shows a map of the Charlotte neighborhoods with the Wilmore and Elizabeth areas outlined.

Figure A.1 here

[29] The Elizabeth brownfield is also near less attractive neighborhoods that has properties in the analysis.

We tested our hypothesis by first removing the observations linked to the Elizabeth brownfield and rerunning our regression model. We then restored the observations for the Elizabeth brownfield, removed those for the Worthington brownfield and reran our regression analyses. Finally, we compared the coefficient for *con_notice* that we found in our original analysis using all of the observations (our baseline results) with the coefficients we found for the test runs. Table A.1 shows the baseline and test run results for both the continuous distance and the discrete distance regressions.

Table A.1 here

The coefficients for the Worthington and Elizabeth brownfields give mixed results. For our hypothesis to be supported, the coefficients for the runs without the Elizabeth and Worthington brownfields must be smaller than the corresponding baseline coefficients. After removing the Elizabeth brownfield, we see that the baseline coefficient is greater than the Elizabeth coefficient at the 0.5 mile (continuous) and the 0.3-0.5 mile ring (discrete). The baseline coefficient, the coefficient without Elizabeth, or both coefficients are statistically insignificant at the 0.75 mile (continuous) and the 0.5-0.75 mile (discrete) distances. The coefficients for the results with Elizabeth removed are greater than the corresponding baseline coefficients for 1 and 1.5 mile (continuous) and the 0.75-1 and 1-1.5 mile (discrete) distances. Finally, the baseline coefficient is very slightly larger than the corresponding Elizabeth coefficients at the 2 mile and 1.5-2 mile groups. Overall, these results seem to suggest that at the short distances, reverse causality may have a slight effect (roughly 1.7-percentage point) on property values affected by the Elizabeth brownfield. This supports the overarching findings that any effects of a brownfield will be felt by properties in close proximity to it. While these results may suggest some reverse causality occurring out to around 0.5 miles, the evidence provided does not convince us that there is a significant upward bias in our baseline (using all observations) coefficients for *con_notice*. Thus we determined that it was appropriate to keep the 420 observations linked to the Elizabeth brownfield in our analysis.

When we removed the observations linked to the Worthington brownfield, the coefficients representing developer application to the Brownfields Program remained consistently higher than the corresponding baseline coefficients for the entire continuous distance results, the opposite of what one would expect if there were reverse causality. Looking to the discrete distance results, we see that the coefficient for the Worthington brownfield, except at the 0.5-0.75 mile distance, is very close to that of the baseline values. [30] However, the coefficient for the baseline is statistically insignificant. Our results are consistent with what Linn (2013) found in his tests for reverse causality, that it was not a sufficient factor to cause an upward bias in the estimated coefficients.

[30] The baseline coefficient at the 0.5-0.75 mile ring is not statistically significant so the large difference between it and the Worthington coefficient cannot be considered valied.

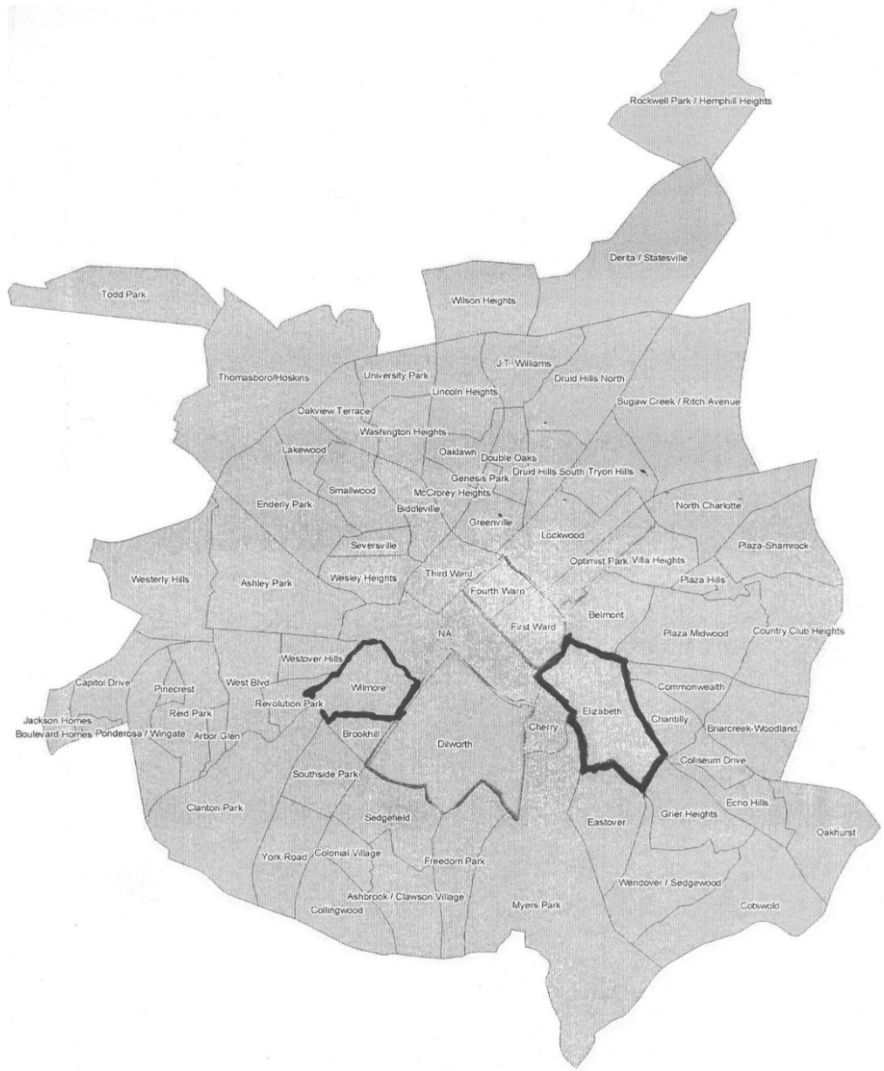

Figure A.1. Map of Charlotte Neighborhoods

Table A.1 Regression Results Testing for Reverse Causality

Regression Identification	**Coefficient for *con_notice***					
Continuous Distance	0.3 mile	0.5	0.75	1	1.5	2
Baseline	0.32663	0.26969	0.0866	0.11587	0.08367	0.06014
(all observations)	(1.91)+	(2.70)*	(2.02)+	(2.12)*	(3.42)**	(3.17)**
Without obs linked to	0.32663	0.25217	0.07643	0.12346	0.08888	0.05996
Elizabeth brownfield	(1.91)+	(2.37)*	(1.57)	(2.06)*	(3.41)**	(3.12)**
Without obs linked to	0.32663	0.27039	0.13765	0.14843	0.08772	0.06333
Worthington brownfield	(1.91)+	(2.69)*	(3.06)**	(2.71)*	(3.50)**	(3.31)**
Discrete Distances	0-0.3 mile	0.3-0.5	0.5-0.75	0.75-1	1-1.5	1.5-2
Baseline	0.32663	0.2664	0.08406	0.16726	0.06147	0.04206
(all observations)	(1.91)+	(2.50)*	(1.22)	(1.75)+	(1.95)+	(1.74)+
Without obs linked to	0.32663	0.25921	0.06135	0.19249	0.06338	0.04157
Elizabeth brownfield	(1.91)+	(2.19)+	(0.77)	(1.80)+	(1.98)+	(1.72)+
Without obs linked to	0.32663	0.2696	0.16827	0.17694	0.06218	0.04374
Worthington brownfield	(1.91)+	(2.51)*	(2.85)*	(1.82)+	(1.93)+	(1.80)+