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The Effect of Voluntary Brownfields Programs on Nearby Property Values

Evidence from Illinois

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RESOURCES FOR THE FUTURE

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Abstract

Brownfields are properties for which redevelopment is hampered by known or suspected contamination and by concerns about associated liability. Because failing to redevelop brownfields may negatively affect welfare and the environment, a number of states have created voluntary programs to reduce liability risks and encourage redevelopment of brownfields. For clean or remediated properties, the state certifies that owners of such sites are not subject to federal or state liability under certain conditions. Certification could increase nearby property values because of decreased contamination risk and amenities associated with redeveloping the brownfield. This paper focuses on the Site Remediation Program in Illinois, and estimates the effect of brownfields certification on nearby property values. Employing several strategies to account for unobserved and time-varying variables that may be correlated with certification, I find that certification of a brownfield 0.25 miles away raises property values by about one percent. In aggregate, the program has increased nearby property values by about two percent.

Key Words: hedonic regression, contamination, voluntary cleanup programs

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The Effect of Voluntary Brownfields Programs on Nearby Property Values: Evidence from Illinois

Joshua Linn*

1. Introduction

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which created the Superfund program. The U.S. Environmental Protection Agency (EPA) can initiate cleanup at sites that pose the greatest threat to human health and the environment. Under the program, property owners and other parties are potentially liable for the cleanup costs, but in many cases public money has been used for cleanup. Since its beginning, considerable debate has focused on the magnitude of the program's benefits. Greenstone and Gallagher (2008) estimate the effect of cleanup on residential property values and conclude that the benefits are smaller than the fiscal costs. However, Gamper-Rabindran and Timmins (2012) find much larger benefits for residential properties located very close to the sites.

The concept of brownfields, which are the focus of this article, arose from the Superfund program. EPA's definition of a brownfield is a property for which "the expansion, redevelopment, or reuse … may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant."[1] By the mid-1990s, it was apparent that potential liability under CERCLA and similar state laws was affecting the resale and redevelopment of brownfields (Higgins 2008; Wang and Godwin 2009). To respond to these concerns, EPA and many states began programs to assess and clean up brownfields and to certify that owners would not be subject to litigation under certain conditions.

The brownfields literature suggests that these programs may correct a market failure that causes insufficient redevelopment from a social welfare perspective. Potential liability under CERCLA reduces the value of a brownfield property. If the market value of the property falls

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[1] See EPA brownfields definition: http://www.epa.gov/brownfields/overview/glossary.htm.

accordingly, the amount and type of redevelopment of the brownfield should be welfare-maximizing. However, property values may not fall enough to encourage optimal redevelopment for several reasons, such as asymmetric information between buyers and sellers and excessive liability costs (Boyd et al. 1996; Chang and Sigman 2007; Wernstedt et al. 2006). In that case, by reducing concerns about liability and pollution, a brownfields certification program could reduce inefficiency. Despite these theoretical arguments, empirical research has found mixed evidence on the benefits of certification programs. A few studies examine the determinants of participation in state voluntary programs (e.g., Alberini 2007; Blackman et al. 2010). Although litigation costs do affect redevelopment (Sigman 2010), the remediation and certification of brownfields does not affect their property values (Alberini 2007).[2]

Whereas these studies focus on the brownfields themselves, certifying and redeveloping brownfields could affect the value of other, nearby, properties. As with Superfund sites, the cleanup can improve human health and the environment surrounding the brownfield, although this effect is likely to be significantly smaller than for Superfund sites because brownfields tend to be less contaminated. Probably more important is the amenity value of cleaning and redeveloping a brownfield. For example, values of nearby properties may have been depressed because the brownfield was a vacant lot; replacing the abandoned site with a new business or house, for example, could raise the value of nearby properties. Some estimates suggest that there may be tens of thousands of brownfields across the United States, many of which are located in urban areas. Because many states have initiated brownfields remediation and certification programs, the aggregate effect of these programs on property values could be quite large.

Estimating the effects of brownfields cleanup or certification on nearby property values faces two main challenges. First, the effects are likely to be very local, which creates a need for precise information about the location of brownfields relative to other properties. Gamper-Rabindran and Timmins (2012) and Davis (2011) demonstrate the importance of estimating local effects in the context of Superfund and the siting of electric power plants. These results suggest that brownfields may affect property values at very local scales, perhaps within a few blocks. Second, unobserved variables correlated with brownfields and reverse causality are two likely

[2] Zabel and Guignet (2010) examine the effect of leaks and cleanup activity for leaking underground storage tanks (LUSTs). They find that more publicized and contaminated sites affect property values. I do not analyze LUSTs in this paper; compared to brownfields, LUSTs probably have somewhat different effects on property values because of their acute nature.

sources of bias. In particular, the presence of a brownfield is likely to be correlated with local (dis) amenities; failing to control for local amenities would bias estimated effects of cleanup or certification.[3] Furthermore, the value of remediating or certifying a brownfield increases with nearby property values, so that rising nearby property values increase remediation or certification; that is, the direction of causality could be from nearby property values to certification, raising the possibility of a spurious result. Just a few studies have examined the effects of brownfields remediation or certification on nearby residential (e.g., Leigh and Coffin 2005) and commercial and industrial (Ihlanfeldt and Taylor 2004) properties, but the existing brownfields literature has only partially addressed the omitted variables issue and has not addressed the reverse causality issue.

I focus on a certification program in Illinois and use extremely detailed data on residential properties and the locations of brownfields. The data contain sales of about 500,000 single-family homes in Cook County. I have very precise data on the locations of the properties and of the brownfields; this allows me to estimate very local effects of certification. I take advantage of the timing of the program and the detailed data to reduce the likelihood of omitted variables bias and reverse causality.

More specifically, I focus on the Illinois Site Remediation Program (SRP), which the Illinois Environmental Protection Agency (IEPA) has run since 1989 (although originally under a different name). A property owner who elects to enter the program pays IEPA to assess the property for contamination. If no contamination is found, IEPA sends the owner a “no further remediation” (NFR) letter that declares the site clean and releases the owner from lawsuits under CERCLA. If contamination is found, IEPA informs the owner what needs to be done to receive the NFR letter. I describe a property as having been certified if the owner has received such a letter.

The main hypothesis to be tested is that the certification of a brownfield raises nearby residential property values. I use three primary data sets that contain (a) sales prices and characteristics of all single-family homes in Cook County, Illinois, which includes the city of Chicago and a number of suburbs; (b) the location, application date, and certification date of all sites in the SRP; and (c) the location and important dates for all sites in the Comprehensive

[3] As discussed below, conditioning on precleanup or precertification prices could reduce this bias, but would not completely do so if amenities were correlated with trends.

Environmental Response, Compensation, and Liability Information System (CERCLIS) database, which includes all sites EPA has investigated for potential remediation under Superfund. I focus on the certification of SRP sites rather than remediation or redevelopment because of data limitations.

I use a hedonic price function to estimate the effect of certification on sales prices of nearby properties. I regress a property's sales price on the density of nearby brownfields that have been certified (Section 3 provides a precise definition of density). For two reasons, a standard hedonic regression of sales prices on brownfields density and property characteristics is likely to yield biased estimates. First, many brownfields are located near old industrial sites, and residential property values tend to be lower in industrial areas. Therefore, a simple cross-sectional regression of property values on certification density would be downward biased; I refer to this bias as arising from the correlation between brownfields density and local amenities. The most common approach to controlling for local amenities in the brownfields hedonic literature is to include Census tract fixed effects (e.g., Leigh and Coffin 2005) or fixed effects at higher levels of aggregation (e.g., zip code). This approach, however, does not address the possibility that local property value trends are correlated with amenities and brownfields density.

Second, the benefit to the owner of certifying a brownfield increases with nearby property values. Sites located in areas with rising property values are therefore more likely to enter the program and receive certification. This raises the possibility of reverse causality, where rising property values cause certification. This issue is particularly important because it suggests that a standard approach to reducing omitted variables bias in a hedonic analysis—by including property fixed effects (i.e., a repeat sales estimator)—would not be sufficient. The problem is that certification is correlated not only with the level of property values but also with trends. The existing hedonic papers on brownfields have not addressed reverse causality.

Several recent Superfund papers have addressed these issues using an instrumental variables strategy that compares sites based on the EPA's evaluation of contamination at each site. Unfortunately, information about contamination is not available for the SRP; this problem is not unique to the SRP, as states seldom provide contamination information. Therefore, I implement a strategy that combines the approach that Gibbons and Machin (2005) use to estimate the effect of public transportation on property values, with the approach that Bajari et al. (forthcoming) use to estimate the effect of air quality on property values. First, I take advantage of the availability of two brownfields databases—CERCLIS and the SRP—and the fact that most sites in the CERCLIS database were evaluated prior to the beginning of the SRP. Analogously to Gibbons and Machin (2005), I condition on the density of CERCLIS sites near the property to control for the tendency of brownfields to be located near industrial areas.[4] Second, I argue, similarly to Bajari et al., that because property values incorporate the expected future value of the property, conditioning on time fixed effects interacted with the lagged median price of nearby properties should address the reverse causality concern. I construct grid squares for all of Cook County that are approximately two city blocks in length. The regression includes grid square fixed effects that control for local amenities. To control for trends, I include interactions of the presample grid square median price interacted with time fixed effects. In contrast, Bajari et al. condition on the past sales price of the same property. My approach avoids the shortcoming of Bajari et al. that only properties sold at least twice can be included in the estimation; in my data, only 33 percent of properties meet this criterion. On the other hand, I have to make stronger assumptions on the component of the error term that may be correlated with observables, in particular, that the component varies by grid square rather than by property. Given these trade-offs, I report results using both approaches below.

I find that certification has increased nearby property values. Sales prices increase by about 1 percent when a brownfield located 0.25 miles away is certified. Overall, the program has increased the average value of all properties within 1.5 miles of certified sites by about 2 percent. The results provide some evidence of larger effects, of about 4–5 percent. These estimates are considerably smaller than regression models that use more aggregated fixed effects to control for local amenities, such as neighborhood fixed effects, and regression models that do not account for reverse causality. This comparison demonstrates the importance of accounting for the correlation between local amenities and brownfields and for reverse causality.

The 2 percent increase corresponds to an increase in total property values of about $2.3 billion (compared to 2007 levels) for the properties in the sample. However, care should be taken when interpreting this estimate because it accounts for the effect of the SRP only on properties located close to the brownfields. The program may have affected other property values in Cook County or elsewhere by affecting redevelopment patterns in the region; the empirical analysis is not able to identify such effects.

[4] One concern with this approach is that, because the SRP is voluntary, the sites in CERCLIS and in the SRP may not be identical; for example, the sites in CERCLIS may be more likely to be former industrial sites than are those in the SRP. This suggests that using the CERCLIS sites to control for proximity to industrial sites may result in bias. This issue is discussed in more detail in Sections 2 and 3; it is addressed by using Toxic Release Inventory data in Section 4.

I also find that entry in the program, as measured by the date of application, has a positive effect on property values. The effects of both entry and certification may occur with a lag of several years. These results are reasonably robust to a variety of other specifications, including implementing the Bajari et al. estimator. In sum, these findings suggest that the SRP has at least partially undone the stigma (Dale et al. 1999) and liability (Sigman 2010) problems associated with brownfields.

The remainder of the paper is organized as follows. Section 2 provides brief descriptions of the Superfund program and the SRP, along with summary statistics on the location and important dates for each site in CERCLIS and for each site in the SRP database. Section 3 describes the empirical strategy and presents summary statistics about property values and characteristics. Section 4 reports the estimation results and Section 5 concludes.

2. Background on CERCLA and the SRP

In the remainder of this paper, a brownfield refers to a site in the SRP or an archived site in CERCLIS. This section briefly describes the two brownfields databases and provides summary statistics from them.

2.1 CERCLA

Under CERCLA, the EPA is informed about a potentially hazardous site and enters the site in CERCLIS. The EPA assesses the site's contamination and risks to human health and the environment. Based on this assessment, the most contaminated and risky sites are placed on the National Priorities List (NPL), and a subset of the NPL sites are cleaned up.[5] Sites that are not placed on the NPL are archived in CERCLIS. In general, the archived sites are not as contaminated or risky as sites on the NPL, but they are often contaminated or are suspected of contamination. Even though the archived sites are not on the NPL, owners and other individuals may still be liable for health or environmental damages.

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[5] There are a few exceptions to the statement that the most contaminated and dirtiest sites are placed on the NPL. For example, states can elect to prioritize sites that would not otherwise be listed.

2.2 SRP

In 1989, Illinois introduced the Pre-Notice Site Cleanup Program, which was renamed the SRP in 1996. The purpose of this program is to provide a mechanism by which owners can have their properties assessed for contaminants, have the contaminants removed or contained if necessary, and receive certification that the property is not liable under state or federal law provided certain use restrictions are met.

Property owners enter the program voluntarily. The typical process includes the initial application, investigation, cleanup, and certification in the form of an NFR letter. The NFR letter states that, as long as the property is used in certain ways and certain precautions are taken for limiting environmental risks, the owner is released from responsibility under the Illinois Environmental Protection Act. The NFR letter is transferred with ownership, and subsequent owners enjoy the same benefits as long as they abide by the letter's stipulations. Under an agreement between the IEPA and the EPA, the NFR letter means that EPA will not take action against the property owner (properties on the NPL are not allowed to enter the SRP). In short, certification reduces substantially the risk of future liability under federal or state law.

From the property owner's perspective, the reduced liability risk is one of the main benefits of receiving an NFR letter. On the other hand, the owner has to pay cleanup, administrative, and any other costs, although some state and federal grant and loan programs can reduce costs. The property owner can apply for loans and grants after entering the SRP.

There are several dimensions of heterogeneity across the sites in the SRP. First, the costs of receiving the letter may vary and reflect the level of contamination or the complexity of controlling or removing the contamination. Second, permitted uses stipulated in NFR letters and actual uses may vary across sites. Third, certification of different types of sites may have different effects on nearby property values. For example, drycleaners may be different from former industrial sites. It is possible to obtain individual records for each brownfield in the SRP from the IEPA, but it would be extremely difficult to collect information about any of these attributes for all brownfields in the SRP.

2.3 Summary Statistics from CERCLIS and the SRP Database

The analysis in this paper is based on two data sets on brownfields, the first constructed from the EPA's CERCLIS and the second from the IEPA's SRP database. The CERCLIS data include all sites that the EPA considered for inclusion on the NPL. Because the data do not include information on contamination or cleanup, I focus on two events: a site's entry in either database and its archiving (for CERCLIS sites) or certification (for SRP sites).

For the CERCLIS data, entry is defined as the first recorded event in the EPA database. The other event I use is the year in which the site is archived, which means that the EPA has determined that the site should not be included on the NPL.[6] Of the 593 Cook County sites in the CERCLIS data, 444 have been archived. Panel A in Figure 1 shows that most of the entry occurred in the 1980s and early 1990s. Archiving peaked in 1995, which reflects EPA's effort to archive sites that had previously been evaluated and for which no subsequent federal Superfund activity would occur.

The SRP data contain 2,916 Cook County sites, including 111 CERCLIS sites. Entry is defined as the date on which the site was first listed in the SRP, and certification is defined as the date on which the NFR letter was issued. Panel B in Figure 1 shows that the rate of entry rose gradually after the program began in 1989 and accelerated in the late 1990s and early 2000s. Certification followed a similar pattern with a delay of a few years; for the sites that were certified by 2011, the average time between entry and certification is two years. Thus, Figure 1 shows that most CERCLIS sites were archived before the SRP sites entered that program.

Figure 2 shows the spatial distribution of the SRP sites. The first map (Panel A) illustrates the location of each site, with the black line indicating the Chicago city limits and O'Hare airport for reference. Most of the sites are located within Chicago, and sites tend to be clustered very close to one another. The large number of sites suggests that property owners were sufficiently concerned about liability to incur the certification costs.

The next two maps in Figure 2 document the proximity of SRP sites to one another by restricting the sample of SRP sites to those located at least 0.25 miles (Panel B) or 0.5 miles (Panel C) from any other SRP site. About three-quarters of the sites are located within 0.25 miles of another site.

Figure 3 compares the locations of the SRP sites with those of the CERCLIS sites. CERCLIS sites tend to be located in areas with many SRP sites.

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[6] The EPA (2002) has noted concerns about the quality of the CERCLIS data, but as explained below, the exact timing of the events is not important—just the fact that most sites in CERCLIS were archived prior to the entry of most SRP sites in the program. Therefore, the data quality concerns should not be a major concern for the purposes of this paper.

3. Estimation Strategy and Property Data

3.1 Estimation Strategy

Similarly to the Superfund literature (e.g., Gamper-Rabindran and Timmins 2012), I estimate a hedonic function in which the sales price of a property is the dependent variable and the property's proximity to brownfields is the main independent variable of interest. This section addresses three issues: (a) whether to analyze entry or certification, (b) how to measure a property's proximity to brownfields, and (c) how to address omitted variables bias and reverse causality.

As the introduction noted, a brownfield can affect the value of a nearby property in at least two ways. First, a property owner may be concerned about the environmental or health effects of being located close to a brownfield. The effect of certification on property values is likely to be larger for Superfund sites than for brownfields because of their lower level of contamination. Nevertheless, uncertainty about contamination and risk aversion by nearby property owners or potential buyers of such properties could cause certification to have a large effect on nearby property values.

Second, concerns about potential liability may prevent the brownfield from being sold or redeveloped. This could reduce the value of a nearby property for many reasons, for example because the undeveloped site is physically ugly or because the redeveloped site would provide an amenity such as a park; thus, failure to redevelop the site reduces the value of the nearby properties compared to the value if the site were to be redeveloped. Although a single brownfield may have a small effect on the value of a particular nearby property, the cumulative effect could be large if many brownfields are near the property. Figure 2 shows how clustered the brownfields are in Cook County, which suggests that the aggregate effect of certification could be large for some properties. Because of both effects of brownfields on nearby property values, I expect that certification would have a positive effect on nearby property values—it would reduce potential buyers' concerns about contamination and would spur nearby redevelopment.

On the other hand, the effect of a site's entry into the SRP on nearby property values depends on how property owners and potential buyers interpret the entry. Consider a particular site, labeled S, the owner of which elects to enter the SRP. Suppose that the likelihood of contamination at S is information held privately by the owner, and that nearby property owners and buyers of such properties initially believe that the probability of contamination at S is zero. Suppose further that if S enters the SRP, cleanup costs have some probability of being sufficiently high that the owner elects not to clean up the property and receive certification.

When owners of nearby properties and potential buyers of such properties observe S entering the SRP, they update their belief about the probability that the property is contaminated. The effect of entry on nearby property values would be negative if the updated probability of contamination and the probability of failing to receive certification are sufficiently high; otherwise the effect of entry is positive. Because the effect is ambiguous, the empirical analysis focuses on the effect of certification on nearby property values, although I also report results for entry.

Thus, the objective is to estimate the effect of certification of a nearby brownfield on the value of a property. As in all previous hedonic studies on Superfund or other potentially contaminated sites, it is necessary to define "nearby"—that is, to use a measure of a property's proximity to a brownfield. The main objective is to define a variable or set of variables that captures the density of brownfields close to a particular property. As Figure 2 suggests, if a property is close to one brownfield, say within a mile, it is probably close to more than one brownfield. Therefore, it is not appropriate to use variables based on the distance to the nearest site (e.g., as in Ihlanfeldt and Taylor 2004), such as a simple dummy variable indicating whether the property is within a certain radius of the brownfield, or the log of the distance to the closest brownfield; such measures would not capture the density of nearby brownfields.

An alternative is to construct a set of count variables equal to the number of brownfields within a given radius. For example, let $S_{it}^{0.25}$ be the number of sites that were certified in year t within 0.25 miles of property i, $S_{it}^{0.5}$ the number of sites that were certified in year t between 0.25 and 0.5 miles of the property. Similar variables could be defined out to any arbitrary distance.

A third possibility is to construct a *gravity* index as the sum of the inverse distance of all brownfields

$$SG_{it} = \sum\nolimits_{d_{ij}<1.5} 1/d_{ij} I_{NFRYear(j)=t} \tag{1}$$

where d_{ij} is the distance between property i and brownfield j measured in miles, and $I_{NFRYear(j)=t}$ is an indicator variable that is equal to one if brownfield j was certified in year t. The summation is taken over all sites within 1.5 miles under the assumption that brownfields located further away do not affect property values. The gravity index places greater weight on nearby sites compared to those further away and, compared to the count variables, has the advantage of using a single variable to measure brownfields density. On the other hand, the gravity measure imposes the assumption that the effect of the brownfield varies inversely with the distance between the property and the site. Although a similar assumption has been made in previous analyses (e.g., Ihlanfeldt and Taylor 2004), it does impose a restriction on the relationship between brownfields density and property values. Because of these trade-offs, I compare results using either the gravity measure or the count variables.[7]

A standard hedonic equation would model the effect of certification on nearby property values, conditional on characteristics of the property

$$\ln p_{it} = \alpha SG_{it} + X_i\beta + \tau_t + \varepsilon_{it} \quad (2)$$

where α is the main coefficient of interest; X_i is a vector of characteristics of the property (which the next subsection specifies) with coefficient vector β that represents the implicit prices of the property characteristics under standard assumptions (Rosen 1974); τ_t is a set of year fixed effects; and ε_{it} is an error term. The sample includes sales of all single-family homes in Cook County for 1993–2007—that is, just after the beginning of the SRP. It is straightforward to estimate this equation given data on characteristics, prices, and brownfields. The hypothesis to be tested is that α is positive, in which case certification increases nearby property values. The positive effect may occur because of the decreased risk of contamination and because of the amenity value of actual or potential redevelopment of the brownfield.

For several closely related reasons, the estimate of α in equation (2) is likely to be biased. First, proximity to a brownfield is probably correlated with unobserved property characteristics. For example, brownfields are often located in previous or current industrial areas, in which residential properties tend to have low amenities—such as school quality—and therefore low property values. Importantly, local amenities may be correlated with levels or trends in property values. Omitting variables related to proximity to industrial areas, or omitting local amenities more generally, would lead to biased results.

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[7] The functional form assumption embodied in the gravity index may be least appropriate for properties located very close to brownfields. For example, certification of 3 sites 0.1 miles from the property has the same effect on the index as the certification of 15 sites 0.5 miles away, yet it is plausible that the latter would have a larger effect in practice. Consequently, in the estimation I omit observations for properties that are in the 99th percentile for the gravity index, which eliminates most properties located very close to numerous brownfields. This restriction does not affect the estimated total effect of the SRP on property values, but it dramatically reduces the standard errors. The results are also insensitive to other restrictions, such as omitting properties within 0.125 or 0.25 mile of a site.

The second reason for potential bias is reverse causality. The owner of a brownfield elects to enter the SRP if the expected benefit outweighs the expected cost, where the benefit includes the value of redeveloping the property and the cost includes administrative and cleanup costs. Suppose that property values in a neighborhood are improving. This raises the value of redeveloping a brownfield, and therefore the value of entering the SRP and receiving certification. Therefore, increases in the dependent variable could cause SG_{it} to increase, in which case α would be biased away from zero.[8]

Finally, characteristics can change over time, and coefficients on characteristics can also change. McMillen (2008) reports changes in coefficients for Cook County using the same data and a similar time period. Assuming constant characteristics (X_i) and coefficients (β), as in equation (2), would bias α .

To specify more precisely the implications of the three issues, I decompose the error term in equation (2) into a component that is correlated with independent variables in equation (2), ξ_{it} , and a component that is not, υ_{it}

$$\ln p_{it} = \alpha SG_{it} + X_i \beta + \tau_t + \xi_{it} + \upsilon_{it} \tag{3}$$

One approach to reducing bias is to compare properties that are located close to a brownfield with properties that are located further away—presumably, outside the effect of the brownfield. The underlying assumption is that ξ_{it} is uncorrelated with the independent variables for properties located close to one another. For example, Zabel and Guignet (2010) compare properties that are very close to underground storage tanks with those that are slightly further away. However, it is not possible to implement this approach for Cook County because brownfields are clustered so closely together. For example, consider a particular SRP site in Figure 3. The "treatment" group may include all properties located within 0.25 miles of the site,

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[8] The possibility of reverse causality precludes a potential approach to addressing the first source of bias, which would be to add to equation (2) a variable measuring the proximity to all sites in the SRP (i.e., $SG_{i0} = \sum_{t\in\{1989,...,2007\}} \sum_{d_{ij}<1.5} 1/d_{ij} I_{NFRYear(j)=t}$). In that case, α would be identified by variation in the timing of certification, in effect comparing the values of properties near SRP sites certified in one year with the values of properties near SRP sites certified in other years. That would address bias caused by unobserved variables correlated with the gravity measure in the cross section, but the reverse causality argument suggests that the timing of certification is endogenous because the owner of the brownfield elects whether and when to enter the SRP.

in which case the “control” group includes all properties 0.25–0.5 miles from the site. Figure 3 shows that most SRP sites are within 0.5 miles of another site. Therefore, many of the properties in the control group for the particular site would actually be located close to another SRP site. The proximity to the other site invalidates the use of these properties as a control group.

The alternative approach that I take is to add controls to equation (3) that address each of the three issues discussed above. I assume that ξ_{it} is composed of four terms: a property’s proximity to industrial sites, local amenities, local property value trends, and changes in the equilibrium values of house characteristics.

I address the first issue—correlation between SRP density and proximity to industrial areas—by conditioning on a property’s proximity to CERCLIS sites. This takes advantage of the timing of Superfund and the SRP. Figure 1 shows that nearly all sites in CERCLIS are archived by 1995, which is precisely when sites were beginning to enter the SRP in large numbers. I define CG_{i0} as the distance to CERCLIS sites, which is computed analogously to SG_{it} as the sum of the inverse distance between the property and all sites in CERCLIS that were archived prior to 1996.[9] In addition to controlling for the property’s proximity to CERCLIS sites, I include interactions of this variable with a set of year fixed effects.[10] The interactions allow the CERCLIS variable to affect property values by different amounts over time.[11]

Next is the possibility that certification is correlated with amenities other than those captured by the CERCLIS variables. I allow such amenities to vary at a very local level and construct a rectangular grid for Cook County such that each side has a length of 0.25 miles; the sides are approximately two city blocks long. Alternatively, I could use neighborhood fixed

[9] Because active or deleted NPL sites are typically much more contaminated than archived CERCLIS sites, the relationship between NPL sites and nearby property values is probably different from that of CERCLIS sites. Consequently, the CERCLIS gravity measure does not include the single NPL site in Cook County. This site does not affect the main empirical results, which are nearly identical to those reported in Table 3 omitting properties within one mile of the NPL site.

[10] The CERCLIS variables control for proximity to past industrial activity. As a sensitivity check in the next section, I use data from the Toxic Release Inventory to control for contemporaneous industrial activity.

[11] It is not precisely true that the SRP began after most CERCLIS sites were archived. Of the 2,916 sites in the SRP, 52 entered prior to 1996, which suggests that a small amount of bias may result from beginning the sample in 1993 rather than 1996. I prefer to use the longer sample to avoid dropping too many sales observations, but I note that the main coefficient estimate is similar, although slightly smaller, using the years 1996–2007 to estimate the regression equation rather than 1993–2007. Likewise, the results are similar if the CERCLIS density variable is constructed using only CERCLIS sites archived prior to 1989.

effects, but the use of the grid squares is motivated by the observation that, in the cross section, most variation in property values is across grid squares rather than across neighborhoods. As I report below, a regression of property values for 1989–1991 (i.e., prior to the estimation sample), on grid square fixed effects has a very high R-squared. Therefore, the grid squares are likely to capture a large share of unobserved amenities.[12]

I use presample prices to control for local trends and address reverse causality. Local property value trends (e.g., at the grid square level) may be driven by a variety of factors, such as changes in amenities. Under a rational expectations assumption (Bajari et al.), local property values should reflect expectations of future trends. Therefore, conditioning on preprogram grid square level prices, interacted with year fixed effects, controls for expected trends in a flexible manner. Assuming that deviations from expectations are uncorrelated with other variables in the estimating equation, the presample prices and interactions account for reverse causality.

In principle, property values during the estimation sample, 1993–2007, could exhibit mean reversion, or the trends could be correlated with past trends. In the case of mean reversion, including the presample median property value by grid square plus interactions of this variable with time fixed effects would control for property value trends during the sample. On the other hand, if prices are not mean-reverting, for example if property values are diverging because of gentrification, it would be appropriate to use the presample property value growth rate by grid square. A priori, it is unclear which approach is preferred. In the main specifications, I assume that prices are mean-reverting and use the presample median price. This is supported by the stronger correlation between sales prices from 1993–2007 and the presample median compared to the correlation between sales prices and the presample growth rate. I include interactions of the presample prices with year fixed effects.

Finally, I add to equation (3) interactions of the property characteristics with a set of period dummies, where periods are defined by five-year time intervals from 1993 to 2007. The interactions allow for the possibility that preferences for characteristics changed over time.[13]

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[12] Another approach would be to use Census block group fixed effects rather than grid square fixed effects. In practice, the number of grid squares is similar to the number of block groups, and the results are similar using the two approaches.

[13] The five-year time intervals are for convenience when reporting coefficients in Section 3.2, and the results are similar using shorter time periods. Unfortunately, characteristics are measured only in 2003, making it impossible to allow the characteristics to vary over time.

I estimate the following equation

$$\ln p_{it} = \alpha SG_{it} + X_i \beta_p + \tau_t + \tau_t CG_{i0} + \gamma_g + \tau_t \overline{p}_{g0} + \upsilon_{it} \tag{4}$$

where β_p is the coefficient vector for time period p, γ_g is a set of grid square fixed effects, and $\tau_t \overline{p}_{g0}$ is the interaction of a set of year dummies with the median price of the grid square in 1989–1991. The estimation sample includes 1993–2007, and the median price is computed for each grid square over the years 1989–1991.

Thus, I specify ξ_{it} in equation (3) as $\xi_{it} = \tau_t CG_{i0} + \gamma_g + \tau_t \overline{p}_{g0} + X_i(\beta_p - \beta_1)$. The main assumption in equation (4) is that, after controlling for proximity to CERCLIS sites, unobserved grid square amenities, mean reversion of property values at the grid square level, and changes in the value of property characteristics, the error term is uncorrelated with the other independent variables. For example, subgrid square trends would not bias the results as long as they are uncorrelated with deviations from grid square means of a property's characteristics.

Bajari et al. propose an alternative approach to controlling for ξ_{it} that allows for a property-specific component of the error term to be correlated with property characteristics (by comparison, equation (4) allows for a grid square level component of the error term to be correlated with property characteristics). The estimation strategy uses repeat sales and effectively conditions on the previous sales price to control for unobserved and time-varying determinants of property values that may be correlated with the variable of interest (in this case, brownfields certification, and in the case of Bajari et al., air pollution). The main limitation of this approach is that a small fraction of my sample is sold more than once. Nonetheless, I compare the results of estimating equation (4) with the other approach in Section 4.6.

3.2 Property Data and Summary Statistics

Here, I describe the data, present summary statistics, and provide some preliminary evidence that the variables in equation (4) are likely to reduce bias from reverse causality and omitted variables; Section 4 provides further evidence. Daniel McMillen provided the data set on property values and characteristics (McMillen 2008; McMillen forthcoming). The Illinois Department of Revenue provided the sales prices and dates along with a unique parcel identification number, which was used to merge the sales data with assessment data from the Cook County Assessor's Office. The sales data span the years 1983–2007, with the exception of 1992. Because most CERCLIS sites were archived by 1996 and the sites began entering the SRP in the mid-1990s, most of the analysis uses prices from 1993–2007. The earlier data, 1983–1991, are used to construct median prices by grid square and presample trends. I restrict the sample to single-family homes because the data are less complete for other types of structures.

The assessment data include standard characteristics of the house, such as the number of bedrooms, square footage of the building, and square footage of the parcel. Each property's address was geocoded, and variables were constructed describing the property's location, such as the proximity to a subway stop (i.e., the "El"), the distance to Lake Michigan, and the distance to the center of Chicago.

Table 1 provides summary statistics for the property characteristics used in the empirical analysis. The table divides the main estimation sample into three five-year time periods from 1993 to 2007. The table shows the mean of each variable, with the standard deviation in parentheses. Each sample includes all properties that were sold during the time period. Because the characteristics are measured in 2003, changes in the averages or standard deviations across periods arise from changes in the distribution of properties that are sold. However, as the table shows, these changes did not affect the means for most variables in an appreciable way, although the distance to the center of Chicago decreased slightly, and the age increased somewhat.

Figures 4–6 provide more detailed information about the temporal and geographic variation of the sales prices. Figure 4 shows that average and median sales prices increased considerably during the sample, although the increase for the upper percentiles is proportionately greater than the increase for the lower percentiles.

Figure 5 shows the estimated density function of the prices for each of the three five-year time periods, and illustrates the same patterns as Figure 4. The distribution clearly shifts to the right (toward higher prices) over time, and the distribution widens considerably between the first and last periods.

Figure 6 illustrates the spatial distributions of prices and price changes. The top panel plots the median price by grid square for 2005–2007. White spaces indicate a lack of sales data, which can occur either because of a lack of development (e.g., in the distant suburbs) or because of a lack of single-family houses (e.g., in downtown Chicago). Dark red indicates higher prices, and the graph is consistent with expectations about the relative prices within Chicago (e.g., the north side vs. the south side) and the suburbs (e.g., Evanston and Oak Park vs. many of the southern suburbs).

The bottom panel shows percentage changes in the median value between the 1993–1995 period and the 2005–2007 period. The largest increases occurred near the center of the city, and many of the surrounding areas experienced relatively small increases—in some cases, as indicated by the dark blue, prices actually decreased.

Table 2 provides some final descriptive information. Each column reports a separate hedonic regression in which the dependent variable is the log of the sales price for property i in year t and the regressions include all of the property characteristics in the data. The following equation is estimated

$$\ln p_{it} = X_i \beta_p + \tau_t + \varepsilon_{it} \tag{5}$$

where X_i is a vector of attributes of the property that includes the same variables as reported in Table 1 as well as neighborhood fixed effects. Each column includes observations from the indicated five-year time period.

The regressions do not include any variables for brownfields, and the purpose of reporting the coefficients here is to demonstrate two points. The first is that, although most of the coefficients are fairly stable over time, some of the coefficients do vary quite a lot, such as the coefficient on log building area. Because certifications increase over time in aggregate (see Figure 1), the changes in coefficients demonstrate the importance of allowing for the possibility that the values of property characteristics change over time. The second observation from the estimated coefficients is that, although they generally have the expected sign and the magnitudes are broadly consistent with the literature, there are a few surprising results. For example, the estimated coefficient suggests that a fireplace increases the value of a property by about 15 percent, which seems unlikely. It is more likely that omitted variables are correlated with the presence of the fireplace, creating upward bias.

I conclude this section by providing some evidence that the control variables in equation (4) are likely to significantly reduce bias from omitted variables or reverse causality. If that were the case, I would expect presample prices to be uncorrelated with future certification after controlling for all of the variables in equation (4). To test this hypothesis, I compute the average cumulative gravity index in 2007 for each property and assign properties to quartiles based on the distribution of this variable. The lowest quartile includes grid squares with very few brownfields and the highest quartile includes grid squares with many brownfields. Using sales prices from 1983–1989, Figure 7 shows the distributions of demeaned log sales prices for properties in each of the four quartiles. Panel A plots the distribution of the log sales price, and the two lower panels plot the distributions of the residuals from regressions of demeaned log sales price on the indicated control variables. The figure shows that the distributions for the four quartiles are very similar to one another when all control variables are included; pairwise tests fail to reject the hypothesis that the means are equal. The results therefore suggest that the control variables in equation (4) effectively address reverse causality and omitted variables bias.

4. Estimated Effects of Certification on Nearby Property Values

This section reports the estimation results. The main conclusion is that, using the gravity measure of brownfields concentration, the certification of a site 0.25 miles away raises property values by about 1 percent. The estimate is fairly robust across a variety of specifications.

4.1 Effect of Entering the SRP and Certification: Gravity Measure

Table 3 reports estimates of equation (4) using the gravity measure of brownfields density. In Panel A the gravity measure is based on entry, and in Panel B the measure is based on certification. Multiplying the estimated coefficient by 4 corresponds to the percentage change in a property's sales price caused by entry or certification of a brownfield located 0.25 miles away. Throughout, standard errors are clustered by neighborhood to allow for correlation within a neighborhood and over time.[14]

Above, I argued that certification is likely to have a larger effect on property values than entry. Column 1 uses entry or certification in the same year as the sale to compute the gravity variables and includes the full set of controls in equation (4). Comparing the column 1 estimates in the two panels, certification appears to have a larger effect than entry, which is consistent with expectations. Furthermore, if I include both entry and certification in the same regression, the coefficients on both variables are positive (not reported). They are not statistically significant, however, perhaps because they are highly correlated. Together with the estimates reported in the

[14] Standard errors are clustered at this level to address the possibilities of local trends in property values and of lagged effects of the SRP on property values. Clustering at this level appears to yield larger standard errors than clustering more finely. For example, for the specification in column 2 of Table 3, the standard errors are about half as large clustering by neighborhood and year rather than clustering by neighborhood.

table, these results suggest that entry raises property values and that certification amplifies this effect.[15]

Columns 1 and 2 compare the results from computing the gravity variable based on entry or certification in the same year (column 1), and the results from computing the gravity variable based on cumulative entry or certification since the start of the SRP. The latter specification is more likely to capture the entire effect of entry or certification because it allows for the possibility that owners of nearby properties learn about entry or certification with a lag or the possibility that redevelopment lags certification. The coefficient on the cumulative variable is about 50 percent larger in both the entry and certification regressions. This suggests that much of the effect of entry or certification on property values occurs within one year.[16] Because the estimates in column 2 are larger than those in column 1, some of the effect of entry or certification probably occurs with a lag. Consequently, the remaining analysis uses the cumulative gravity variable, and I refer to column 2 in Panel B as the baseline.

The baseline estimate is statistically significant at the 1 percent level, and the magnitude suggests that certifying a site raises the values of properties 0.25 miles away by about 1 percent. The elasticity of property values to the gravity measure is 0.022.[17]

The other columns in Table 3 compare the estimates of α when sequentially adding the control variables in equation (4). Column 3 includes only neighborhood fixed effects and the property characteristics from Table 3, and therefore does not account for reverse causality or amenities at the subneighborhood level. The coefficient is much larger than the baseline in column 2. Compared to column 3, allowing the coefficients on the property characteristics to

[15] As noted above, very few characteristics of the SRP sites are included in the public database; this makes it difficult to assess whether the effects of certification vary across different types of sites. It is possible to test whether effects on property values are different for CERCLIS sites or drycleaners in the SRP. However, the SRP includes only 111 CERCLIS sites, which makes it difficult to detect an effect of their entry or certification. Although drycleaners are likely to have some contamination, they tend to be relatively small sites, making certification less likely to have a large effect on property values. In practice, the certification of CERCLIS sites or drycleaners does not have a noticeable effect on nearby property values.

[16] One of the specifications in the robustness analysis, in Section 4.4, further confirms that property values respond with some lag to certification. Using certification from the previous two years yields smaller estimates than using certifications in all previous years (see column 5 in Table 6).

[17] As Figure 2 shows, the concentration of SRP sites is much greater within Chicago than elsewhere in Cook County. The greater density suggests that the relationship between certification and nearby property values may be different for Chicago than for the rest of the county, but the results are fairly similar, although smaller, for Chicago. Restricting the sample to properties in Chicago, the elasticity of nearby property values to the gravity index is 0.015.

vary across periods (column 4) and adding the CERCLIS gravity–year interactions (column 5) does not affect the results, although the CERCLIS variables are negative and statistically significant as expected. In column 6, adding grid square fixed effects to control for unobserved amenities causes the estimate to decrease substantially. The decrease suggests that some unobserved characteristics vary at the grid square level and are correlated with the gravity variable; it also demonstrates the importance of including such detailed geographic controls. Recall that in Table 2, some of the coefficients on the property characteristics, such as the fireplace dummy variable, suggested that omitted variables were correlated with the characteristics. However, adding the grid square fixed effects causes the coefficients to be much more reasonable—the coefficient on the fireplace dummy, for example, decreases from about 0.15 to about 0.02. Sections 4.5 and 4.6 present further evidence that the control variables in the baseline specification substantially reduce bias caused by omitted variables or reverse causality.

To summarize, Table 3 shows three main results. First, both entry and certification have positive effects on property values. Second, the estimate of α is positive and statistically significant in the baseline specification, which is column 2 in Panel B. Third, the other columns show the particular importance of including grid square fixed effects.

4.2 Effect of Entering the SRP and Certification: Distance from Property

Section 3.1 noted that the gravity measure has the advantage of summarizing brownfields density in a single variable. The disadvantage is that it imposes a functional form assumption on the relationship between distance and the sales price—specifically, that the log price varies inversely with distance.

To assess whether this assumption affects the results, Table 4 reports the same specifications as Table 3, except using a series of count variables instead of the gravity variable. For example, Panel B includes the total number of certified sites within 0.125 miles, as well as the total number of sites between 0.125 and 0.25 miles, and so on out to 1 mile from the property. If the functional form is appropriate, the coefficients should decrease linearly with distance—for example, the coefficient on the 0.75–0.875 variable should be approximately one-third the magnitude of the coefficient on the 0.25–0.375 variable.

The baseline specification in column 2 of Panel B shows several results. First, the effects for sites 0.125–0.25 miles away are similar to those for sites less than 0.125 miles away. Further than 0.25 miles away, the coefficients decrease steadily. This pattern suggests that certification (or perhaps subsequent redevelopment) may have a small negative effect on the very closest properties, but that this effect is quite localized. Unfortunately, the lack of data on the characteristics of the certified sites themselves makes it impossible to investigate the reasons for this result.

Second, except for the sites within 0.125 miles, the coefficients exhibit the expected pattern of decreasing with distance to the certified site. The decrease in the coefficients is roughly consistent with the gravity measure used in Table 3, which Figure 8 demonstrates. The solid line without boxes shows the point estimates from Table 4 and the dashed lines show the 95 percent confidence intervals. For comparison, the solid line with boxes is constructed to intersect with the point estimate at a distance of one mile. For other distances, the line indicates what the coefficients would be if the gravity measure correctly describes the relationship between distance and property values; the gravity variable is appropriate if the solid line is reasonably close to the boxed line. Some of the coefficients lie above the gravity equation line, and in a few cases the difference is statistically significant. However, I demonstrate, in two ways, that the difference is not economically large. First, the implied average effect of the SRP on property values is similar using the estimates from Table 3 and Table 4—that is, about 2 percent. Second, the largest deviation in Figure 8 is for sites within 0.125 miles of the property, but the estimated effect of the SRP on average property values is similar to the baseline using the gravity equation but omitting properties within 0.125 miles of a certified site. Because of these results, the remaining analysis uses the gravity index; the main conclusions are the same using the count variables.

4.3 Results by Price Decile

Gamper-Rabindran and Timmins (2012) find that remediation of Superfund sites has a larger effect on property values at the lower end of the price distribution than at the upper end. A similar effect would occur for brownfields if property values in poorer neighborhoods are depressed more (in percentage terms) by a failure to redevelop brownfields; in that case, certification would have a larger effect in poorer areas than in wealthier ones.

I take an approach similar to Gamper-Rabindran and Timmins by assigning each property to 1 of 10 deciles based on the median property value for the corresponding grid square during the presample period, 1989–1991. Table 5 shows estimates of α using the baseline specification and restricting the sample to each of the 10 deciles in columns 1–10. Overall, the estimates suggest that the effect of remediation is, in fact, larger for the lower price deciles. The average coefficient for the bottom five deciles is about twice the average coefficient for the top five deciles, and the difference is statistically significant at about the 1 percent level.[18]

4.4 Functional Form Assumptions

Tables 6–8 report a number of variants of the baseline specification. Columns 1 and 2 of Table 6 show that outliers do not affect the estimate of α . Column 1 omits the top and bottom 5 percent of the price distribution and the estimate is quite similar to the baseline. For column 2, I estimate the baseline regression and compute the ratio of the residual to the dependent variable. Dropping the top and bottom 5 percent of the distribution of the ratio and reestimating equation (4) does not affect the point estimate.

In a given year, the gravity variable varies considerably across properties. This suggests that a log-linear model may be more appropriate than the baseline, which imposes the assumption that an additional certification has the same effect on property values whether the concentration of brownfields is high or low. In column 3, the elasticity is 0.008. This should be compared to column 4, which uses the level of the gravity variable rather than the log, but restricts the sample to observations with positive values of the gravity variable to match with column 3, which only includes such observations by construction. The elasticity in column 4 is 0.017, which is about twice the elasticity in column 3. This suggests that the baseline estimates may somewhat overestimate the effect of the SRP, but most other reported specifications in this paper are very similar to the baseline.

The baseline specification uses a gravity measure computed as the cumulative sum of the inverse distance of all past certifications. Column 5 shows that the estimate is considerably smaller using the certifications in the current and two previous years rather than in all previous years. The estimate using the current and previous four years is close to the baseline (not reported). These results suggest that there is some lag between certification and the increase in nearby property values. The lag is consistent with the hypothesis that redevelopment following certification raises nearby property values.

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[18] The mean of the cumulative NFR letter variable varies across deciles, but the estimated elasticity of property values to NFR letters is larger for the lower deciles than for the higher deciles.

4.5 Omitted Variables and Reverse Causality

The remainder of Table 6 and Tables 7 and 8 take a number of approaches to address the possibility that omitted variables or reverse causality bias the baseline estimate. Specifically, I add further control variables that may be correlated with other omitted variables, I add leads of certification to assess possible reverse causality, and I compare the baseline estimates with the estimates obtained using the Bajari et al. methodology.

The baseline specification uses the interaction of the presample median price with time fixed effects, allowing for the possibility that trends are correlated with the presample price—in other words, that prices are mean-reverting. Alternatively, the trends may be persistent, in which case it would be more appropriate to use interactions of presample trends with year fixed effects. Column 6 of Table 6 shows that using trends rather than levels does not affect the results.

Equation (4) conditions on all CERCLIS sites that are archived by the end of 1995. The baseline specification does not include other CERCLIS sites, that is, sites that are archived after 1995 and sites that are active at the end of the sample. I do not include these sites because there are very few of them. Nevertheless, they could affect property values and bias the results. For column 7, I construct a CERCLIS gravity measure that is similar to the SRP certification measure and is based on CERCLIS sites archived from 1996 to 2007. The coefficient on this variable is small and is not statistically significant, suggesting that archiving CERCLIS sites does not affect property values. In another specification, including a gravity measure based on active CERCLIS sites does not affect the results (not reported).

The CERCLIS variables control for disamenities correlated with brownfields density, such as past industrial activity. Brownfields density may also be correlated with contemporaneous industrial activity and pollution. I gather data from EPA's Toxic Release Inventory (TRI), which contains data on emissions into air and other media from industrial sources. Each of the 915 TRI facilities in Cook County could have a unique effect on property values depending on the specific chemicals emitted and other factors. However, computational limitations prevent me from allowing each facility to have a unique effect on property values. Consequently, I impose the assumption that facilities in the same industry have the same effect on property values. However, the effect can vary across industries and years. I compute a gravity index for each of the 209 four-digit SIC industries in the TRI data. I estimate a separate coefficient on the gravity index for each industry and year, which allows for industry-specific annual fluctuations in emissions, perceived risks, and other factors associated with the facilities.

Column 8 shows that adding these variables reduces the estimate of α by about one-quarter, but the estimate is statistically significant.

Another potential concern with the baseline specification is that borrowing costs may affect property values and that borrowing costs varied considerably over the sample period. The time fixed effects control for the average effect of borrowing costs on property values, but borrowing costs could differentially affect property values. Column 9 adds to the baseline the interactions of borrowing costs, as measured by the real interest rate (the difference between the interest rate including fees and charges and the Consumer Price Index), with the property characteristics in Table 1. Adding these interactions does not affect the results.

A more flexible way of addressing the possibility of omitted and time-varying variables correlated with brownfields density is to include interactions of neighborhood fixed effects with time trends. This approach controls for localized trends that may not be fully controlled for using the presample variables. Column 10 includes interactions between neighborhood and linear and quadratic time trends. The results are quite similar to the baseline.

Table 7 addresses the possibility of reverse causality, in which positive trends cause certification. If this is true, and the trends persist across multiple years, the trends should be correlated with future entry and certification. Therefore, the estimate of α would decrease if leads of certification are added to the baseline. The coefficient on future certifications itself is harder to interpret; the coefficient could be positive either if past and future certifications are positively correlated or if housing market participants anticipate the effects of future certification on property values. In either case, in the absence of reverse causality, the coefficient on future certifications would be positive, but the coefficient on past certifications would be similar to the baseline. Columns 1–4 of Table 7 use leads of varying length for the main sample.[19] Although future certification is correlated with property values, the main coefficient is not affected.

Column 5 shows that the coefficient on certification is larger using the years 1983–2007 instead of the baseline sample, but the average effect of the SRP on property values is about 2

[19] To prevent spurious correlation, the leads variables reflect certification of sites that were not previously in the SRP in the given year. To see this, suppose that the one-year lead for time t includes all sites that are certified in year $t + 1$. Some of those sites may have already entered the SRP in year t, in which case, adding the one-year lead would cause the estimate of α to decrease even if reverse causality is not present. Therefore, the leads variables exclude sites that had already entered the SRP as of year t.

percent, which is similar to the baseline. The results in columns 6–9, which include leads, are similar to those for 1–4, and suggest that reverse causality does not bias α .

4.6 Other Regression Models Accounting for Omitted Variables and Reverse Causality

Table 8 compares the baseline estimates with several other approaches to addressing bias from omitted variables or reverse causality. First, Table 3 showed that adding grid square fixed effects reduces the estimate of α substantially. Because property characteristics are highly correlated within a grid square, the decrease raises the possibility that there are omitted, but time-invariant, local amenities at the subgrid square level or that unobserved property characteristics are correlated with the independent variables. To address these possibilities, column 2 of Table 8 uses a repeat sales estimator by including property fixed effects and restricting the sample to include only properties that are sold at least twice during the sample. The estimate should be compared to the estimate in column 1, which uses the same sample as column 2 but includes grid square fixed effects rather than property fixed effects; the two estimates are nearly identical.

The few existing brownfields hedonics studies, such as Leigh and Coffin (2005), have attempted to control for local amenities using fixed effects at the Census tract or higher levels of aggregation. For comparison with the baseline and the repeat sales estimator, column 3 includes a set of Census tract fixed effects in place of the grid square fixed effects. The estimate of α is similar to the baseline in Table 3.

One concern with including grid square fixed effects to control for local amenities is that the fixed effects could exacerbate measurement error in the gravity variable and bias α toward zero. Column 4 compares the estimates using equation (4) with the estimates obtained using the Bajari et al. methodology. Instead of relying on grid square fixed effects to control for local amenities, Bajari et al. develop a rational expectations model of property values, in which lagged sales prices and lags of the independent variables control for unobserved property-specific variables. The specification includes property characteristics, the Census gravity variable, the presample grid square price, neighborhood fixed effects, and lags of the sales price and gravity variable; importantly, the regression does not include grid square fixed effects. I modify the Bajari et al. approach slightly so that the sample matches that of columns 1 and 2 and includes all repeat sales as well as interactions between the number of years since the last sale and the independent variables (including all main effects). The estimate in column 4 of Table 8 is about twice as large as that in column 1, but it is much smaller than the estimates in columns 3–5 of Table 3, which likewise do not include grid square fixed effects. Thus, the results using the grid square fixed effects or using the rational expectations estimator imply that the SRP has raised property values by broadly similar amounts, by 2–5 percent. Across all the reported specifications, the overall effect of the SRP ranges from 1 to 5 percent, with most specifications suggesting around 2 percent.

5. Conclusions

In this paper, I investigate the effect on nearby property values of the Illinois brownfields program, the SRP. In the SRP, the state certifies that sites can be used in certain ways without fear of litigation under CERCLA. I attempt to control for potentially confounding influences on property values by conditioning on the concentration of other brownfields and on the median value of nearby properties prior to the start of the SRP. For single-family homes in Cook County from 1993 to 2007, certification of a site raises the sales price by about 1 percent for a property located 0.25 miles from the site. On average, the SRP has increased the values of properties within 1.5 miles of certified sites by about 2 percent. The results provide some evidence for larger effects, of about 4–5 percent. The effect decreases approximately inversely with the distance between the brownfield and the property. Furthermore, the effect appears to be stronger for low-price houses.

This paper is among the first to estimate the effect of state brownfields certification programs on property values. Besides examining other programs, future work should address a number of questions. First, the IEPA does not provide data on administrative costs, private cleanup costs, or public cleanup costs, making it impossible to perform a rigorous comparison of the program's costs and benefits. Although these costs are likely to be much lower than the costs of Superfund, additional research is needed to perform such an analysis. Second, the initial motivation for programs such as the SRP was to offset the depressing effects of CERCLA on redevelopment and nearby property values. It is unclear how the estimated increase in property values compares with this initial decrease. Finally, because certification affects the values of nearby properties, in the long-run equilibrium (i.e., allowing for changes in the housing stock), certification affects development and values of properties throughout the region (Jenkins et al. 2006). Understanding these effects is important for evaluating the overall costs and benefits to society of brownfields programs, but very few studies have examined them.

6. References

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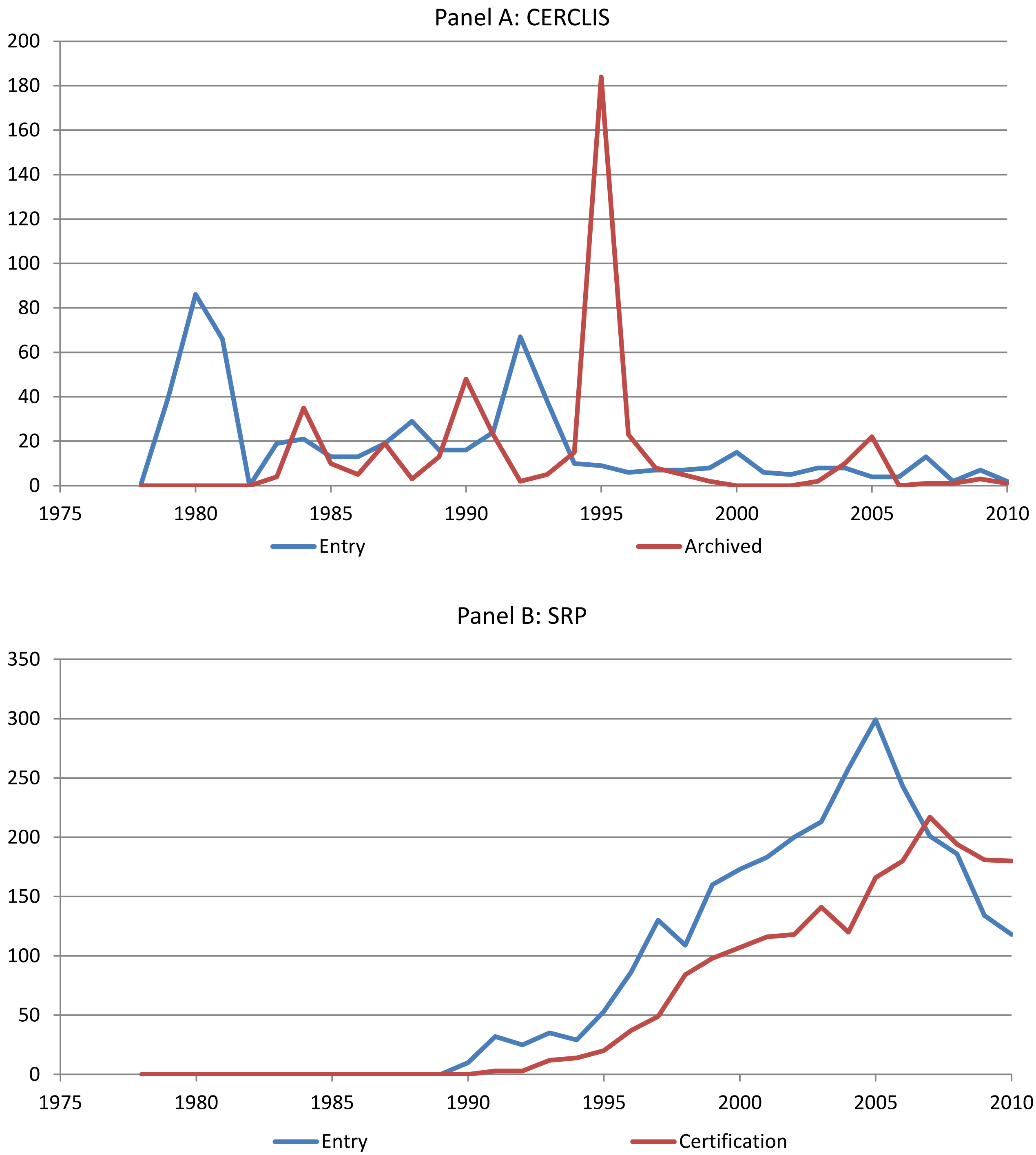
Figures and Tables

See following pages.

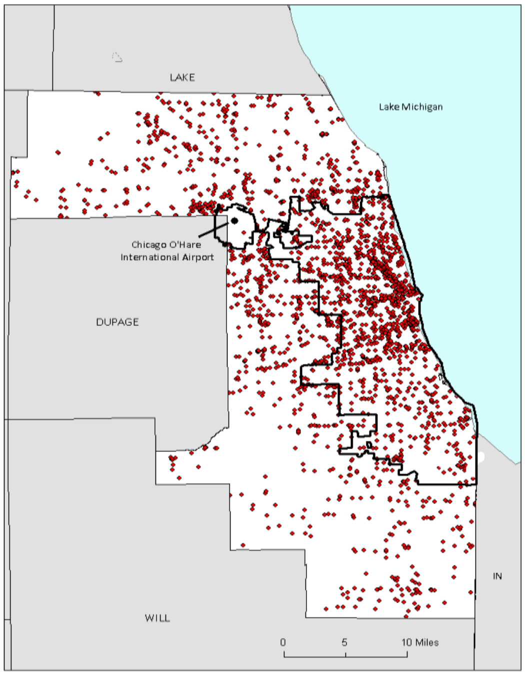
Figure 1. SRP and CERCLIS Entry and Exit by Year, 1978–2010



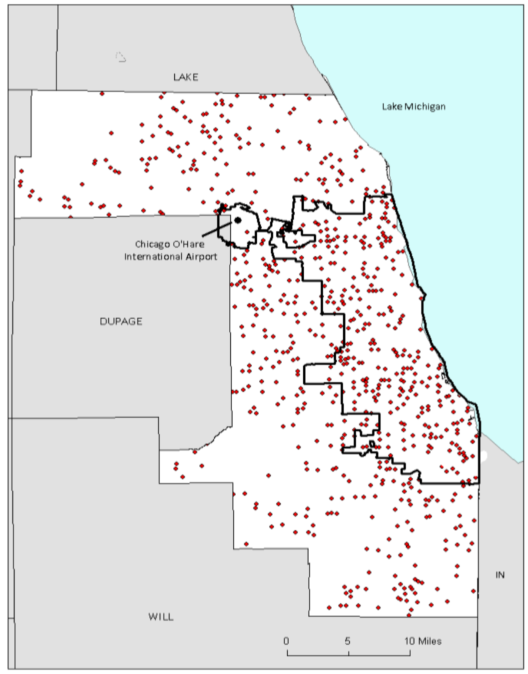
Notes : Panel A plots the number of new (entering) sites in CERCLIS by year and the number of sites that were archived. Panel B plots the number of sites entering the SRP by year and the number of sites receiving an NFR letter (certified).

Figure 2. Locations of SRP Sites

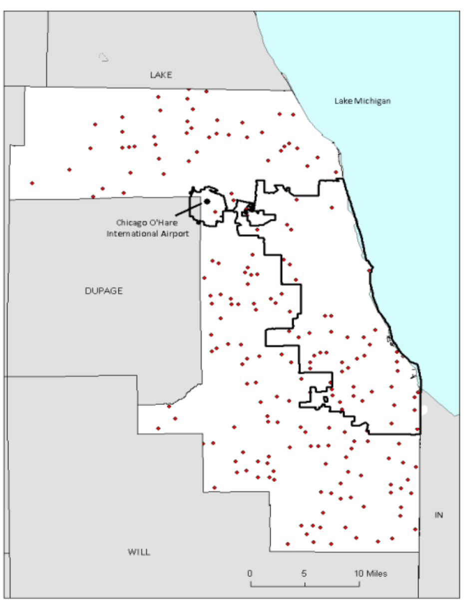
Panel A: All sites



Panel B: Sites at least 0.25 miles from closest other SRP site

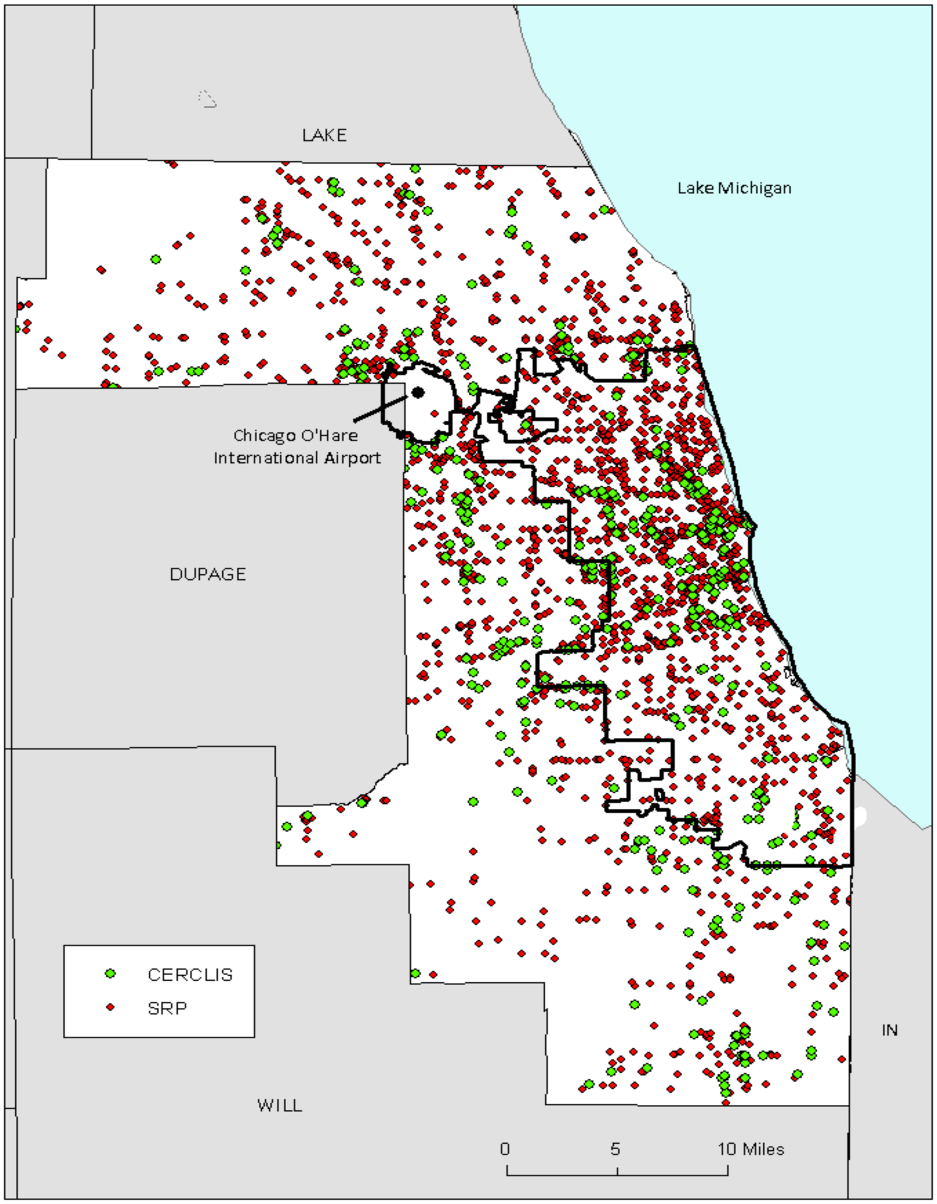


Panel C: Sites at least 0.5 miles from closest other SRP site



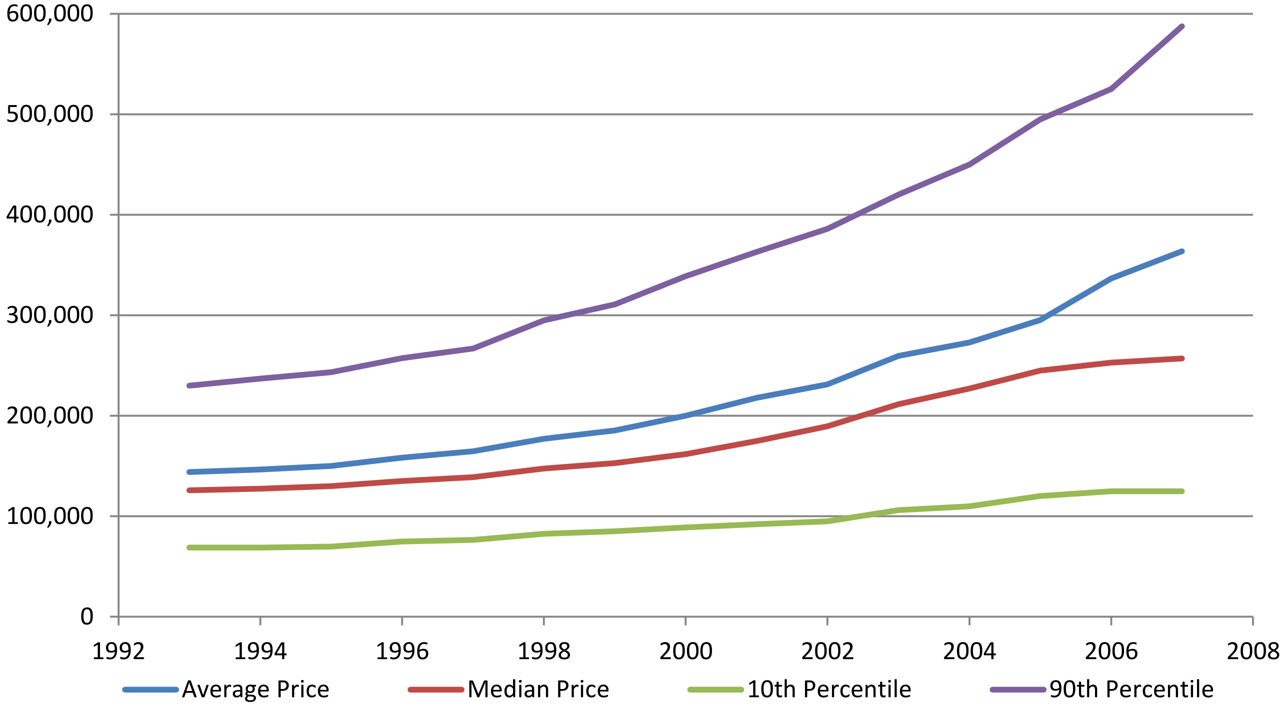
Notes : Panel A plots the locations of all SRP sites. Panel B includes sites for which no other site is within 0.25 miles. Panel C includes sites for which no other site is within 0.5 miles. The black lines in Cook County indicate the Chicago city limits and O'Hare airport.

Figure 3. Locations of SRP and CERCLIS Sites



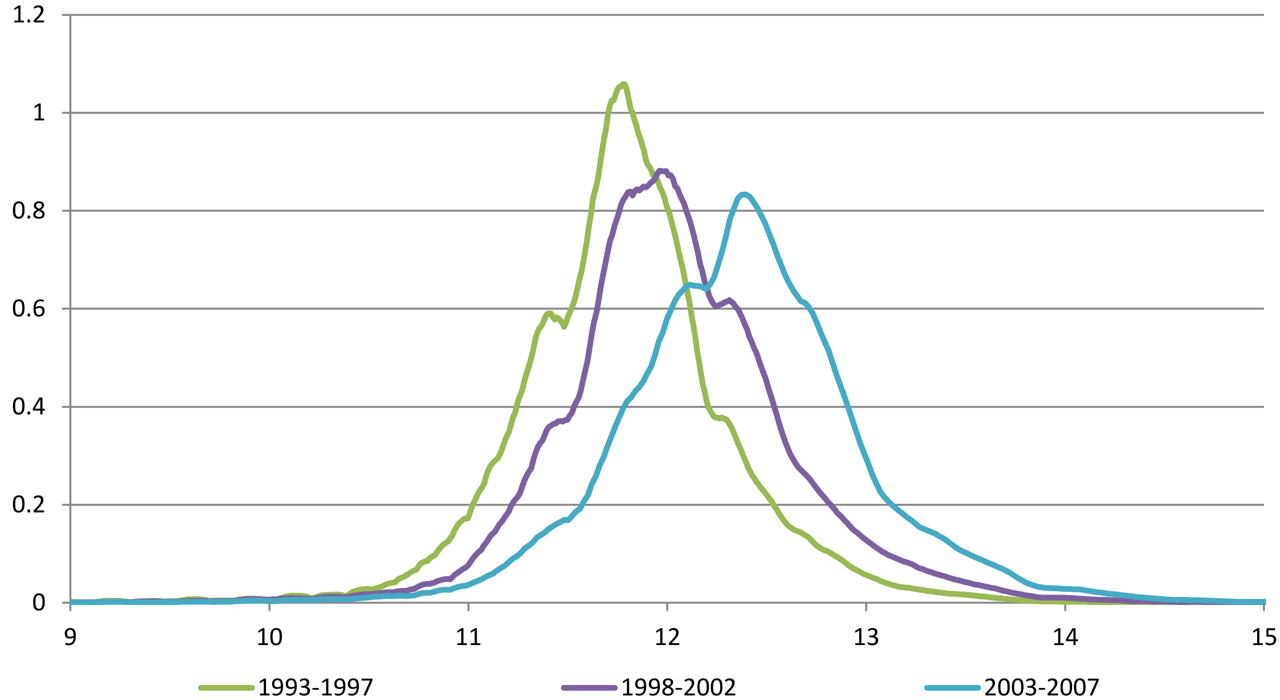
Notes : The map shows the location of all SRP sites and all CERCLIS sites that were archived prior to 1996.

Figure 4. Cook County Sales Price, 1993–2007



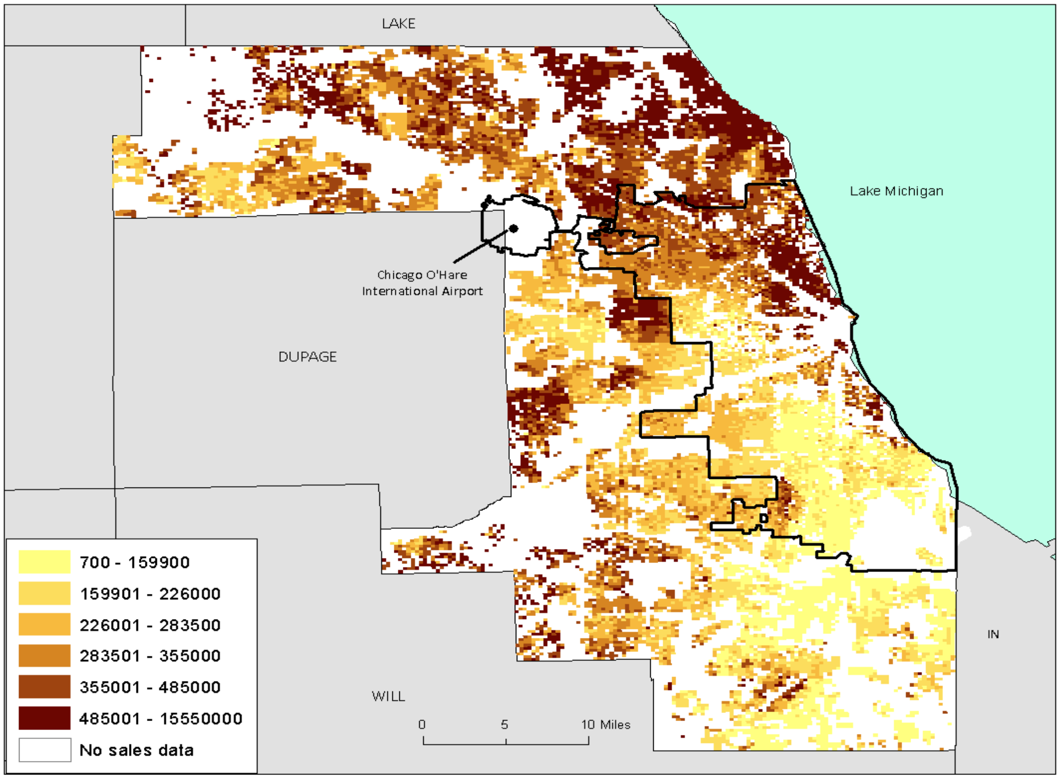
Notes : The figure plots the average price, median price, 10th percentile, and 90th percentile of the sales price by year for all properties in the estimation sample, in current dollars.

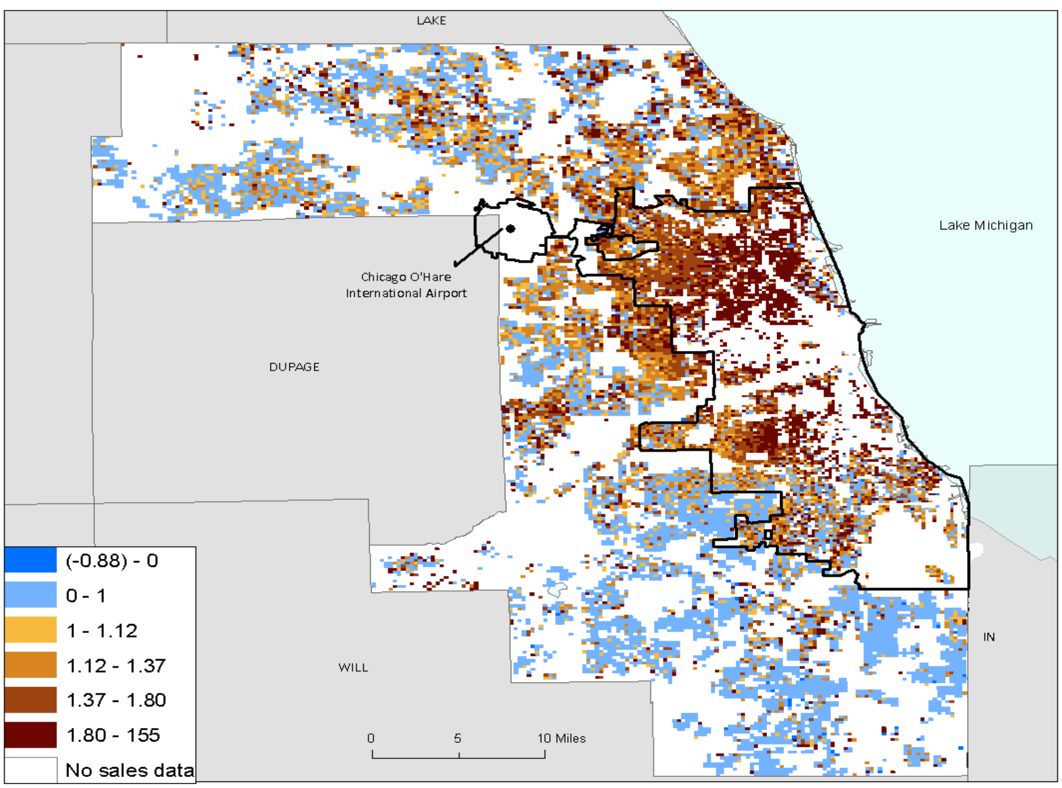
Figure 5. Density Function of Log Sales Price by Five-Year Period



Notes : The figure plots the estimated kernel density function of the price of all properties sold during the indicated time period.

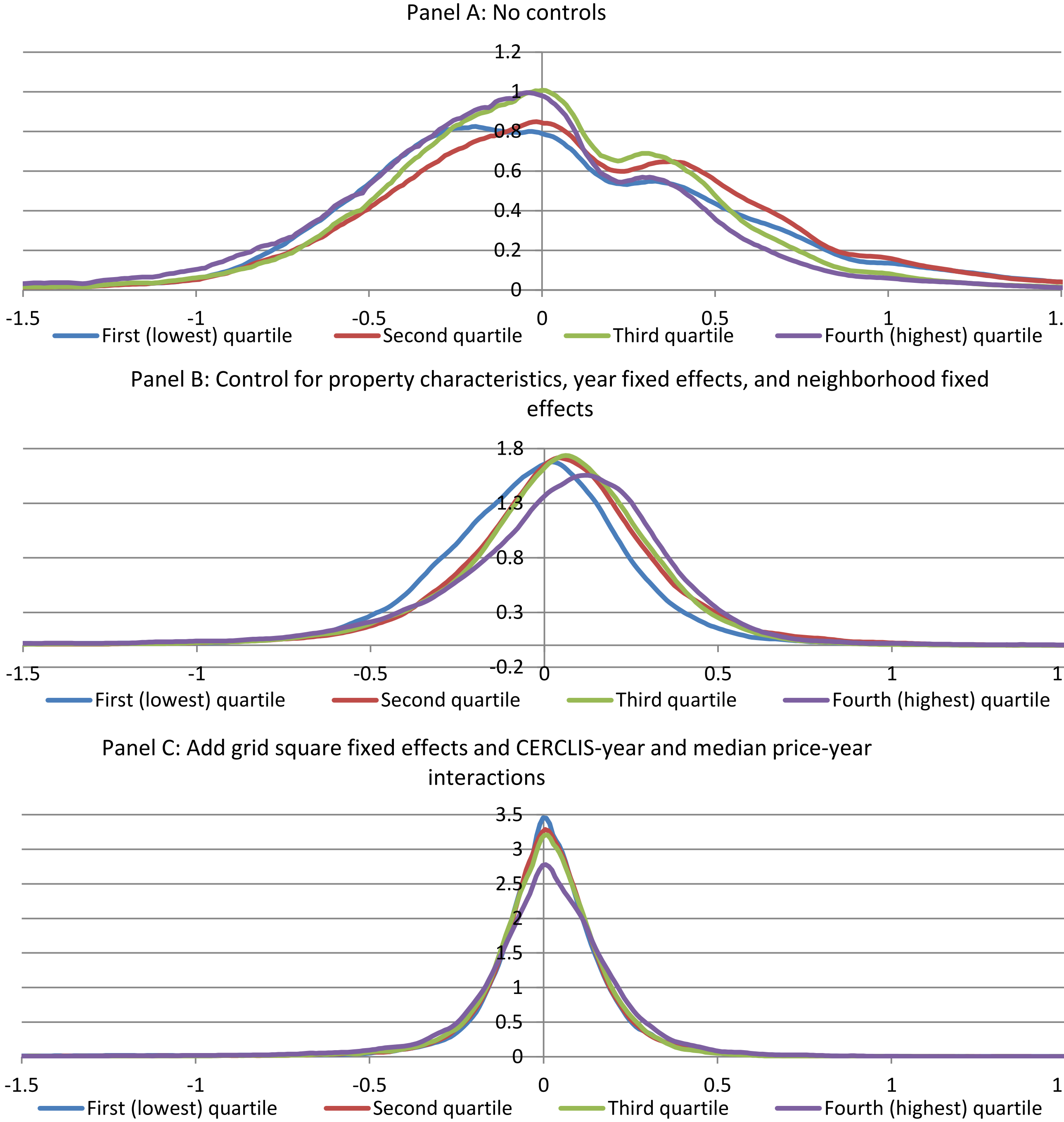
Figure 6. Median Sales Price (2005–2007) and Percentage Change (1993–2007)





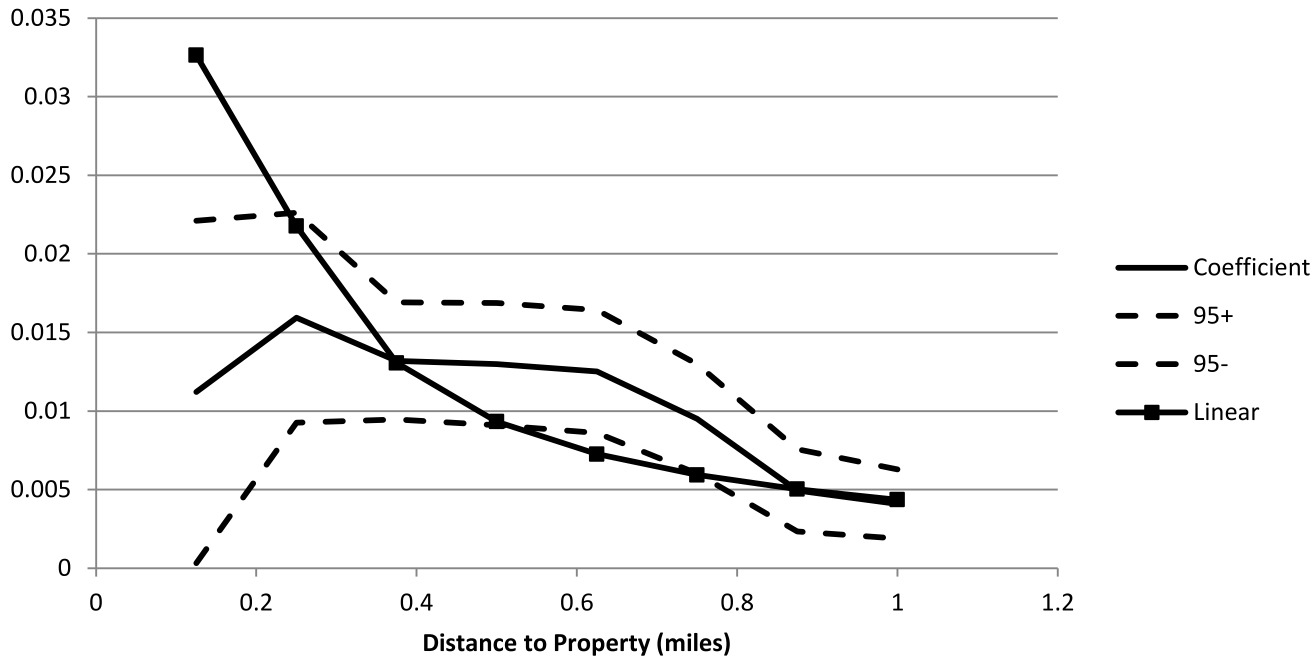
Notes : The top panel shows the median sales price by grid square using all sales from 2005–2007. The bottom panel shows the fractional change in median price by grid square from 1993–2007. The legends in the bottom corners of the panels indicate the correspondance between the colors and the values of the variables.

Figure 7. Density Functions of 1983–1989 Sales Prices by SRP Quartile



Notes : Each property is assigned a quartile based on its cumulative SRP gravity in 2007. The first quartile includes properties with the lowest SRP gravity and the fourth quartile includes properties with the highest. Panel A plots the estimated kernel density functions of the demeaned log sales price of properties in 1983–1989 including properties in each of the four quartiles. Panel B plots estimated density functions of the residuals from a linear regression of the demeaned log sales price on the property characteristics in Table 1, neighborhood fixed effects, and year fixed effects. The median grid square price is computed using sales prices in 1989–1991. Panel C plots density functions of residuals from a linear regression that adds grid square fixed effects, CERCLIS gravity-year interactions, and median grid square price-year interactions.

Figure 8. Comparing Estimated Coefficients and Gravity Model



Notes : The solid curve without boxes plots the estimated coefficients from column 6 in Table 4 against the distance from the property to the SRP sites. The dashed curves show the 95 percent confidence intervals. The solid curve with boxes shows what the estimated coefficient would be if the coefficient varies inversely with the distance from the property, as in the gravity equation. The curve is constructed to pass through the coefficient estimate for 0.875–1 miles.

Table 1.

Characteristics of Purchased Homes by Five-Year Period

Variable	1993–1997	1998–2002	2003–2007
Log land area (sq ft)	8.67 (0.56)	8.66 (0.57)	8.62 (0.57)
Log building area (sq ft)	7.19 (0.35)	7.19 (0.36)	7.16 (0.35)
Number of rooms	5.95 (1.39)	5.95 (1.41)	5.85 (1.38)
Number of bedrooms	3.08 (0.78)	3.07 (0.78)	3.02 (0.77)
Number of bathrooms	1.56 (0.64)	1.56 (0.66)	1.51 (0.63)
Has central air conditioning	0.42 (0.49)	0.42 (0.49)	0.38 (0.49)
Has brick exterior	0.63 (0.48)	0.63 (0.48)	0.61 (0.49)
Has fireplace	0.26 (0.44)	0.26 (0.44)	0.23 (0.42)
Has 1-car garage	0.27 (0.44)	0.27 (0.44)	0.27 (0.45)
Has garage for 2+ cars	0.59 (0.49)	0.58 (0.49)	0.56 (0.50)
Miles to city center	15.58 (7.03)	15.48 (7.08)	15.17 (7.05)
Within 0.25 miles of el stop	0.02 (0.13)	0.02 (0.14)	0.02 (0.14)
Within 0.5 miles of lake	0.01 (0.09)	0.01 (0.09)	0.01 (0.09)
Within quarter mile of rail stop	0.26 (0.44)	0.26 (0.44)	0.29 (0.45)
Age at time of sale	44.95 (24.34)	49.41 (25.28)	56.29 (26.12)
Number of Observations	153,785	156,389	171,477

Notes : All characteristics are from the 2003 assessment data. The sample in each column includes all properties sold during the indicated time interval. The city center is the intersection of State and Madison.

Table 2.

Hedonic Regression by Five-Year Period

Variable	1993–1997	1998–2002	2003–2007
	Dependent Variable: Log Sales Price		
Log land area (sq ft)	0.230 (0.014)	0.205 (0.015)	0.244 (0.018)
Log building area (sq ft)	0.482 (0.021)	0.540 (0.022)	0.520 (0.023)
Number of rooms	0.002 (0.003)	0.007 (0.003)	0.007 (0.003)
Number of bedrooms	-0.002 (0.005)	-0.011 (0.005)	-0.038 (0.005)
Number of bathrooms	0.082 (0.006)	0.083 (0.005)	0.108 (0.007)
Has central air conditioning	0.062 (0.008)	0.063 (0.008)	0.072 (0.010)
Has brick exterior	0.012 (0.010)	-0.011 (0.010)	-0.034 (0.013)
Has fireplace	0.147 (0.014)	0.154 (0.016)	0.160 (0.017)
Has 1-car garage	0.089 (0.009)	0.076 (0.008)	0.065 (0.011)
Has garage for 2+ cars	0.068 (0.009)	0.053 (0.008)	0.038 (0.010)
Miles to city center	-0.011 (0.002)	-0.016 (0.002)	-0.028 (0.003)
Within 0.25 miles of el stop	0.158 (0.062)	0.243 (0.067)	0.197 (0.073)
Within 0.5 miles of lake	0.408 (0.099)	0.455 (0.102)	0.374 (0.126)
Within 0.25 miles of rail stop	-0.110 (0.015)	-0.114 (0.017)	-0.126 (0.019)
Age at time of sale (age/10)	-0.010 (0.004)	-0.004 (0.004)	-0.013 (0.004)
Number of Observations	153,785	156,389	171,477
R-squared	0.59	0.57	0.52

Notes : The table reports estimates from equation (5), where each column includes sales from the indicated five-year time period. Standard errors are in parentheses and are clustered by neighborhood. Besides the reported independent variables, all regressions include year fixed effects; neighborhood dummies; and dummies for an attic, a finished attic, a basement, and a finished basement. The age of the house is divided by 10.

Table 3.

Effect on Property Values of Entering SRP and Receiving NFR Letter

	Dependent Variable: Log Sales Price					
	(1)	(2)	(3)	(4)	(5)	(6)
Specification	Baseline, current gravity measure	Baseline, cumulative gravity measure	House chars, year fixed effects, ngbrhd fixed	Add chars x period interactions to (3)	Add CERCLIS gravity measure to (4)	Add grid square fixed effects to (5)
	Panel A: Effect of Entry					
New entry (gravity)	0.0021 (0.0004)					
Cumulative entry (gravity)		0.0029 (0.0003)	0.0085 (0.0010)	0.0079 (0.0011)	0.0097 (0.0013)	0.0031 (0.0003)
Number of observations	482,056	482,056	482,056	482,056	482,056	482,056
R Squared	0.84	0.84	0.63	0.63	0.63	0.84
	Panel B: Effect of NFR Letter					
New NFR letter (gravity)	0.0025 (0.0004)					
Cumulative NFR letters (gravity)		0.0035 (0.0004)	0.0143 (0.0014)	0.0135 (0.0016)	0.0153 (0.0017)	0.0038 (0.0004)
Number of observations	481,651	481,651	481,651	481,651	481,651	481,651
R Squared	0.84	0.84	0.63	0.63	0.64	0.84

Notes : The table reports the estimated coefficient on the gravity variable from equation (4). The sample includes properties sold from 1993 to 2007. All regressions include the same independent variables as in Table 2. In Panel A the gravity variable is computed using the year of entry into the SRP, and in Panel B the gravity variable is computed using the year the SRP sites receive NFR letters. In column 1 the gravity variable is computed using sites that enter or receive a letter in the same year as the sale. In columns 2–6 the gravity variable includes all sites that enter or receive a letter in all previous years. Periods are defined for five-year time intervals from 1993 to 2007. Columns 1–2 and 4–6 include the interactions of the house characteristics with a set of period fixed effects. Columns 1–2 and 5–6 include a gravity measure computed from CERCLIS sites that are archived no later than 1995. Columns 1–2 and 6 include grid square fixed effects to column 4. Columns 1–2 include interactions of year fixed effects with the CERCLIS gravity variable, as well as interactions of year fixed effects with the median grid square house price from 1989–1991.

Table 4.

Property Value Effects by Distance

	Dependent Variable: Log Sales Price					
	(1)	(2)	(3)	(4)	(5)	(6)
Reported indep variables:	New entry/NFR	Cumulative entry/NFR	Cumulative entry/NFR	Cumulative entry/NFR	Cumulative entry/NFR	Cumulative entry/NFR
	Panel A: Effect of Entry					
Within 0.125 miles	0.0080 (0.0064)	0.0139 (0.0058)	0.0513 (0.0113)	0.0456 (0.0114)	0.0450 (0.0111)	0.0140 (0.0058)
0.125–0.25 miles	0.0143 (0.0033)	0.0164 (0.0030)	0.0414 (0.0072)	0.0379 (0.0075)	0.0411 (0.0071)	0.0162 (0.0030)
0.25–0.375 miles	0.0060 (0.0029)	0.0123 (0.0019)	0.0294 (0.0045)	0.0267 (0.0048)	0.0333 (0.0045)	0.0120 (0.0019)
0.375–0.5 miles	0.0049 (0.0022)	0.0106 (0.0016)	0.0275 (0.0044)	0.0249 (0.0047)	0.0338 (0.0046)	0.0101 (0.0017)
0.5–0.625 miles	0.0032 (0.0020)	0.0064 (0.0020)	0.0180 (0.0041)	0.0159 (0.0041)	0.0220 (0.0047)	0.0062 (0.0019)
0.625–0.75 miles	0.0048 (0.0013)	0.0050 (0.0012)	0.0131 (0.0032)	0.0115 (0.0032)	0.0155 (0.0037)	0.0048 (0.0012)
0.75–0.875 miles	0.0016 (0.0013)	0.0037 (0.0010)	0.0133 (0.0033)	0.0116 (0.0033)	0.0155 (0.0034)	0.0036 (0.0009)
0.875–1 miles	0.0047 (0.0012)	0.0050 (0.0009)	0.0176 (0.0036)	0.0151 (0.0038)	0.0188 (0.0037)	0.0049 (0.0008)
R Squared	0.84	0.84	0.62	0.63	0.63	0.84

Table 4 (cont.):

			Panel B: Effect of NFR Letter			
Within 0.125 miles	0.0153 (0.0079)	0.0112 (0.0056)	0.0761 (0.0147)	0.0701 (0.0149)	0.0678 (0.0138)	0.0115 (0.0055)
0.125–0.25 miles	0.0145 (0.0046)	0.0159 (0.0034)	0.0590 (0.0092)	0.0551 (0.0094)	0.0577 (0.0090)	0.0157 (0.0035)
0.25–0.375 miles	0.0079 (0.0041)	0.0134 (0.0019)	0.0497 (0.0072)	0.0463 (0.0074)	0.0514 (0.0071)	0.0132 (0.0020)
0.375–0.5 miles	0.0111 (0.0025)	0.0130 (0.0020)	0.0443 (0.0069)	0.0411 (0.0071)	0.0486 (0.0069)	0.0127 (0.0021)
0.5–0.625 miles	0.0063 (0.0024)	0.0125 (0.0020)	0.0411 (0.0047)	0.0377 (0.0050)	0.0453 (0.0050)	0.0122 (0.0020)
0.625–0.75 miles	0.0062 (0.0019)	0.0095 (0.0018)	0.0329 (0.0052)	0.0302 (0.0053)	0.0362 (0.0055)	0.0094 (0.0018)
0.75–0.875 miles	0.0041 (0.0014)	0.0049 (0.0013)	0.0212 (0.0047)	0.0190 (0.0047)	0.0230 (0.0048)	0.0050 (0.0013)
0.875–1 miles	0.0024 (0.0011)	0.0041 (0.0011)	0.0233 (0.0049)	0.0206 (0.0049)	0.0237 (0.0049)	0.0041 (0.0011)
R Squared	0.84	0.84	0.63	0.63	0.63	0.84

Notes : Specifications are the same as in Table 3 except that the regressions replace the gravity measure with a set of variables measuring the total number of sites located a given distance from the property. The total number of entering sites is computed for various distances (in miles) from the property, and similarly for the total number of new NFR letters. Column 1 includes these variables as independent variables. Columns 2–6 include the sum since 1990 of each of these variables.

Table 5.

Effects of NFR Letters on Property Values by Decile of Property Value

	Dependent Variable: Log Sales Price									
	First (lowest) decile	Second decile	Third decile	Fourth decile	Fifth decile	Sixth decile	Seventh decile	Eighth decile	Ninth decile	Tenth (hightest) decile
Cumulative NFR letters (gravity)	0.0043 (0.0013)	0.0071 (0.0012)	0.0033 (0.0009)	0.0034 (0.0009)	0.0050 (0.0007)	0.0037 (0.0007)	0.0027 (0.0006)	0.0014 (0.0006)	0.0029 (0.0007)	0.0007 (0.0011)
Number of observations	33,930	50,189	54,259	61,372	59,912	55,081	51,078	43,657	39,749	32,424
R Squared	0.59	0.64	0.68	0.74	0.75	0.75	0.76	0.75	0.73	0.75

Notes : The table reports the same specification as column 6 of Panel B in Table 3. The median house price is computed for each grid square over 1989–1991. Each grid square is assigned a decile from lowest to highest median house price. Each column reports a separate regression in which the sample is restricted to include properties located in grid squares that belong to the decile indicated at the top of the table.

Table 6.

Robustness Checks: Outliers, Alternative Gravity Measures, CERCLIS Sites, and Other Controls

	Dependent Variable: Log Sales Price									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Specification	Drop dep var outliers	Drop residuals outliers	Log gravity	Drop if gravity = 0	Use past 2 years to compute gravity	Grid square pre-trends x year	Add post-1995 archived CERCLIS sites	TRI gravity X year fixed effects	Mortgage rate X property character-istics	Neighbor-hood X quadratic time trends
Cumulative NFR letters (gravity)	0.0035 (0.0003)	0.0034 (0.0003)	0.0084 (0.0030)	0.0023 (0.0004)	0.0021 (0.0004)	0.0035 (0.0004)	0.0035 (0.0004)	0.0024 (0.0004)	0.0035 (0.0004)	0.0031 (0.0004)
Archived CERCLIS (gravity)							-0.0004 (0.0005)			
Number of observations	434,034	433,487	330,335	330,335	481,651	456,020	481,651	481,338	481,651	481,338
R Squared	0.88	0.95	0.83	0.83	0.84	0.84	0.84	0.84	0.84	0.85

Notes : The table reports the same specification as column 6 of Panel B in Table 3 except as indicated in the column headings. For each year, the 5th and 95th percentiles of sales price are computed. Column 1 omits observations below the 5th and above the 95th percentiles. Residuals are computed from the specification in column 6 of Panel B in Table 3. Column 2 omits observations below the 5th and above the 95th percentiles of the ratio of the residual to the dependent variable. Column 3 uses the log of gravity rather than the level. Column 4 omits observations for which the gravity measure equals zero. Column 5 uses NFR letters in the current and past two years to compute the gravity measure rather than all current and past NFR letters. The median price by grid square is computed for the years 1983–1985 and 1989–1991. Column 6 adds interactions of year dummies with the percentage growth in median property value between 1983–1985 and 1989–1991. Column 7 includes a gravity measure for all CERCLIS sites archived after 1995. The inverse distance is computed between each property and each Cook County facility in the Toxic Release Inventory (TRI) data. Gravity indexes are computed for each of the 209 4-digit SIC industries. Column 8 includes the interactions of year fixed effects with the 209 gravity indexes. Column 9 includes the interactions of the real mortgage rate with the property characteristics in Table 1. Column 10 includes interactions of neighborhood fixed effects with linear and quadratic time trends.

Table 7.

Anticipation Effects

	Dependent Variable: Log Sales Price								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Specification	1-year lead	2-year lead	3-year lead	4-year lead	Sample includes 1983–2007	1983–2007, with 1-year lead	1983–2007, with 2-year lead	1983–2007, with 3-year lead	1983–2007, with 4-year lead
Cumulative NFR letters (gravity)	0.0036 (0.0004)	0.0037 (0.0004)	0.0038 (0.0004)	0.0039 (0.0004)	0.0062 (0.0007)	0.0062 (0.0076)	0.0062 (0.0007)	0.0061 (0.0007)	0.0062 (0.0007)
Future NFR letters (gravity)	0.0037 (0.0008)	0.0027 (0.0005)	0.0026 (0.0004)	0.0025 (0.0004)		0.0076 (0.0011)	0.0051 (0.0007)	0.0048 (0.0006)	0.0046 (0.0006)
Number of observations	481,651	481,651	481,651	481,651	778,656	778,656	778,656	778,656	778,656
R Squared	0.84	0.84	0.84	0.84	0.86	0.86	0.86	0.86	0.86

Notes : The table reports the same specification as column 6 of Panel B in Table 3 except as indicated in the column headings. Column 1 adds a gravity measure computed from sites that received NFR letters in the next year, but which had not entered the SRP in the current year or earlier. Column 2 adds the gravity measure based on sites that received NFR letters in the subsequent two years, but which had not entered the SRP in the current year or earlier. The three and four-year leads are constructed similarly in columns 3 and 4. Column 5 includes all sales from the years 1983–2007 and omits the CERCLIS controls and interactions of the year dummies with the 1989–1991 median grid square sales price. Columns 6-9 add to column 5 the corresponding lead NFR variables from column 1–4.

Table 8.

Comparison of Fixed Effects and Rational Expectations Estimators

	Dependent Variable: Log Sales Price			
	(1)	(2)	(3)	(4)
Regression model	Baseline spec using repeat sales sample	Repeat sales sample with property fixed effects	Baseline sample with Census tract fixed effects	Rational expectations
Cumulative NFR letters (gravity)	0.0032 (0.0005)	0.0036 (0.0006)	0.0028 (0.0004)	0.0066 (0.0006)
Number of observations	253,811	253,811	481,651	142,053
R Squared	0.85	0.92	0.83	0.78

Notes : Standard errors are in parentheses and are clustered by neighborhood. Column 1 repeats the baseline specification from Table 3 using properties that are sold at least twice from 1993 to 2007. Column 2 uses the same sample as column 1 and includes property fixed effects instead of grid square fixed effects. Column 3 uses the same sample as in Table 3 and includes Census tract fixed effects instead of grid square fixed effects. Column 4 reports the specification from Bajari et al. (2012). Besides the reported gravity index, the regression includes interactions of the number of years since the prior sale with the lag property value, lag of the gravity index, the CERCLIS gravity variable, the presample grid square median price, and the property characteristics used in the baseline regression. The regression also includes neighborhood fixed effects.