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The Effect of an Incinerator Siting on Housing Appreciation Rates*

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Several studies have documented a decline in property values due to the existence of an undesirable facility, but most examine only two points in time. One study found declines in house values near an incinerator at several points in time, which were due to changes in information. This suggests that the adjustment period can be quite long; if prices do not adjust immediately, the house's appreciation rate will reflect the speed of adjustment. This study finds that appreciation rates are affected as early as the construction stage of an incinerator, and the adjustment continues several years after the facility has begun operation.

I. INTRODUCTION

Public opposition to the siting of locally unwanted land uses is growing in this country, especially as the number and types of such sites expand and as people become more aware of the risks and costs associated with these facilities. The literature on the impact of unwanted facilities on property values is well known, with various studies documenting one-time declines in property values in the vicinity of an undesirable facility. However, little attention has been focused on the effects of these facilities on property appreciation rates. Differences in appreciation rates capture

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the speed of adjustment to new price levels and are evidence of a disequilibrium in the housing market due to the presence of the facility.

Determining whether, when, and by how much the location of a facility affects appreciation rates is necessary in order to correctly estimate the cost of such facilities. If prices adjust completely and immediately then the change in price can be measured at any two points before and after the siting, as the effect of the impact will not change over time. If the price level adjustment takes time, then the appreciation rate is negatively influenced and the impact on the homeowner cannot be quickly measured. Only two previous studies have considered the effect of hazardous facilities on appreciation rates, and they have utilized either survey or aggregate data, which may confound the issues.

This paper uses a unique data set to study the impact of the siting of an incinerator in North Andover, Massachusetts on housing appreciation rates in the surrounding area. Two approaches, an income capitalization model and a repeat sales technique, are developed to examine the relationship between appreciation and the location of the house relative to the incinerator. Changes in the probability of an incinerator siting and in the likelihood of damage are also considered.

The results from both approaches indicate that appreciation rates are positively affected by distance from the incinerator, although the strength of the effect varies over the siting process. Thus, individuals who live close to an incinerator will experience declines in housing values, and the adjustment between price levels will take time. Because long-run equilibrium requires appreciation rates to be the same across a housing market, the observed differences in appreciation rates reveal that the local housing market has not fully adjusted to the facility, even after 7 years of operation.

II. PREVIOUS STUDIES OF THE IMPACT ON HOUSE VALUES AND APPRECIATION RATES

Several studies have examined the relationship between a house's value and its distance from an undesirable land use. Gamble and Downing [4] and Twark *et al.* [16] examine the impact of the accident at the Three Mile Island nuclear power plant on local house prices. They find that the price of the house increases with distance from the plant. Kohlhase, in a study of toxic waste dumps in Houston [9], and Michaels and Smith [12], in their examination of toxic sites in Boston, find the same result. Mendelsohn *et al.* [11] look at the contaminated harbor in New Bedford, Massachusetts and find that zones further from the site have higher prices. These studies all attempt to hold constant other factors that might influence price in order to isolate the impact of the undesirable land use.

Other studies have shown a link between air quality and property values. In general, the pollution in the area studied did not arise from a single source, such as an incinerator, but from many unspecified sources. Nonetheless, the effects of an undesirable facility on properties may be similar to the effects of poor air on properties since both affect all houses within a given distance indiscriminately. See Smith and Huang, ([15], Appendix A) for a bibliography of the air quality literature.

None of the earlier studies allow for changes in the probability of the plant arriving (Galster [3]) or for changes in the expected damages attributed to the site. Kiel and McClain [8] incorporate these changes in information through time in their study of an incinerator in North Andover, Massachusetts. They divide the siting process into five stages. The first stage is the period prior to any discussion of the siting of a facility, and represents "normal" market activity in the area. The second stage begins when the project is proposed to the community, and represents the "rumor" phase of the siting. If the siting is approved, the third stage, the "construction" phase, begins and continues until the facility goes on line. The fourth stage starts when the plant goes into operation and ends when the market has fully adjusted to the presence of the facility, representing the "operation" phase. The fifth and final stage occurs once the market has adjusted to the presence of the facility. It should be similar to the first phase, although the equilibrium prices may be higher or lower than in the first phase depending on how the (dis)amenity is valued. Kiel and McClain demonstrate that changes in the price levels occur in each stage, even after controlling for the location of the facility relative to each house. This indicates that people adjust to changes in information about the possibility of the site and about the extent of damage from the site.

Given evidence that house price levels are affected over long periods of time by undesirable facilities, housing appreciation rates will be affected. A variety of other factors have been shown to influence individual housing appreciation rates in the short run, including the user cost of owning a home, which is a function of marginal tax rates, interest rates, maintenance costs and depreciation (Mayer [10]), and the characteristics of the house and its neighborhood (Dale-Johnson and Phillips [2], Kiel and Carson [7]). Characteristics may affect appreciation rates because adjustment to changes in the supply of and/or demand for these characteristics does not occur immediately, creating a short run disequilibrium in the market for these aspects. If proximity to an incinerator is considered an important characteristic of the house, then it can influence the appreciation rate.

Greenberg and Hughes [6] and Greenberg and Anderson [5] have studied the impact of hazardous waste sites on housing appreciation rates. In the first paper, the authors surveyed the tax assessors of 567 civil divisions in New Jersey in February 1992. Thirty-seven of the 90 towns with at least one site on the EPA's National Priority List responded, and 113 of the 477 without a site responded. They found that

> Tax assessors report that hazardous waste sites have lowered the appreciation of property values, deterred land uses, and affected community plans in about 15% to 20% of the New Jersey towns that report hazardous waste sites. Nearly all of these impacts occur within one-fourth mile of the site [p. 50].

Their study did not control for the rapid price increases that New Jersey experienced in the 1980s, and they state that their work "cannot replace detailed price estimation" [p. 51].

Greenberg and Anderson use median house price data to study the impact on appreciation rates. Property values for 18 dumpsite communities with populations of less than 15,000 were compared to values for the remainder of the county they were located in, using 1960, 1970, and 1980 Census data. They found that

> As a group the property values and rents in the 18 dumpsite communities have appreciated more than those of the remainder of their counties... It cannot be concluded that dump sites have *so far* had a consistent, detrimental impact on property values in the communities in New Jersey with the worst dumpsites [p. 145–146].

However, since many of the sites were not listed by the EPA until the late 1970s or early 1980s, it is unclear whether their results are due to sites or, again, to the rapid appreciation in the area.

III. A MODEL OF HOUSING APPRECIATION RATES

An undesirable land use, such as an incinerator site, could affect housing appreciation rates if the disamenity is an important component of the bundle of housing attributes. Potentially relevant aspects of the facility include distance between the house and the incinerator, changes in the probability of the incinerator going on line, and changes in the expected damages due to the facility. If changes in the supply of and/or the demand for any of these aspects of the facility occur, house prices will be affected. If the prices do not adjust immediately, appreciation rates will be affected. Once the market has adjusted completely, rates will stabilize at the market level.

In order to test for the effect of distance and stage of siting on appreciation rates, house values (V) are modeled by

$$V(t) = \int_T^\infty R_0 e^{\alpha t} e^{\Sigma_i \mu_i \mathrm{DUM}_i t} e^{-rt}\, dt, \qquad (1)$$

where α is the rate at which rents appreciate, μ_i is the appreciation rate during each of the incinerator siting phases where i indexes the phases, DUM_i is a series of indicator variables for each of the phases, and r is the discount rate. The integral yields

$$V(t) = \frac{R_0 e^{-(r-\alpha-\Sigma_i \mu_i \mathrm{DUM}_i)T}}{r - \alpha - \sum_i \mu_i \mathrm{DUM}_i}. \tag{2}$$

Taking logs of both sides produces

$$\ln V(t) = \ln R_0 - (r - \alpha)T + \sum_i \mu_i \mathrm{DUM}_i T - \ln\Big(r - \alpha - \sum_i \mu_i \mathrm{DUM}_i\Big). \tag{3}$$

This model is estimated two ways. First, Eq. (3) is estimated directly using information on sales prices of houses over time, characteristics of the house and neighborhood which might influence rents, and a time trend that will capture appreciation and discounting. Indicator variables on the period during which the sale took place interacted with the time trend variable will also be included; the estimated coefficients on these variables will equal zero if appreciation rates are constant across periods.

Second, repeat sales data are used for houses which sold twice during a specified period. The two sales prices (values) are used to calculate an average annual appreciation rate over the time span between s and t

$$\mathit{APPRECIATION\ RATE} = \exp\left(\frac{\ln[V_t / V_s]}{t - s}\right) - 1, \tag{4}$$

then regressions are run to determine what affects the individual rates. Because changes in supply of and demand for various characteristics of the dwelling have been found to affect appreciation rates, these characteristics are included in the regressions (although the equation indicates that they should cancel out). The appreciation rate experienced by housing unit i during a time period j is modeled as a function of the characteristics of the house and its neighborhood, including the distance from the house to the incinerator. Incorporating an interaction term between distance and the phase indicator allows the impact of distance to change through time.

The repeat sales approach has some limitations (see Kiel and Carson [7]). First, houses that sell more than once during a phase may be different from houses that do not, leading to a sample selection bias. Second, it reduces the number of observations available, thus making the estimation less efficient (Case *et al.* [1]).

IV. ESTIMATING THE INCOME CAPITALIZATION MODEL

The model is estimated with data from the North Andover, Massachusetts Tax Assessor's Office. North Andover has a total area of 27.85 miles and is located approximately 20 miles north of Boston near several major highways. The data set was constructed by searching the deeds to find all arms' length single-family house sales that occurred in North Andover between January 1974 and May 1992. Sales between family members or where one of the parties was a realty or brokerage firm were excluded. The sales price and date were obtained from the deed and house characteristics were collected using the Assessor's data. Houses with changes in characteristics were excluded. The sample contains 2593 sales.

All five siting stages discussed above are included in the data set. The first stage is from 1974 through 1978. The possibility of an incinerator that turned refuse into electricity was first mentioned in the town's newspaper in 1978, thus the rumor phase is from 1979 through 1980. The construction phase is from 1981 through 1984, and the operation phase is 1985 through 1988. The final period is from 1989 through May 1992.

Definitions, means, and standard deviations of the variables used in the income capitalization approach (Eq. 3) are given in Table 1, column 1. To control for appreciation over time in the New England region, the dependent variable (PBI) is the log of the sales price of each home deflated by a Boston house price index (National Board of Realtors [14]). This assumes that changes in price levels in the area around North Andover due to regional factors are captured by the appreciation experienced in the Boston metropolitan area during the time period under consideration.

The regression results are in Table 2. The age of the unit (AGE) and its square (AGESQ), the log of distance from the house to the incinerator (LNDIST), the area of the unit (AREA), and the lot size (LAND) are included to explain differences in rents (R_0 in Eq. 3). The estimated coefficients have the expected signs. Sales price declines with the age of the house and then increases, reflecting homes in North Andover that are desirable for their historical characteristics. Both the area of the living space and the lot size increase the sales price of the house. The natural log of the distance variable (LNDIST) allows for the effect of the incinerator to decrease at a decreasing rate as distance increases, but being further from the facility is always advantageous. The coefficient is positive and statistically significant. Interaction terms between the log of distance from the incinerator and the phase indicators which are indexed by i

TABLE 1
Variable Descriptions and Sample Statistics

Name	Description	Income capitalization data mean (std. deviation) (1)	Repeat sales data mean (std. deviation): All repeat sales (2)	Phase 1 1974–1978 (3)	Phase 2 1979–1984 (4)	Phase 3 1985–1992 (5)
Number of observations		2593	310	53	112	145
SALES PRICE	Nominal transaction price of house	157,841 (104,495)				
BOSTON INDEX	Nominal median price of existing single family homes for the Boston MSA in hundreds of dollars	1085.11 (490.13)				
PBI	House sales price divided by Boston house price index	140.73 (57.01)				
LNPBI	Natural log of PBI					
APP100	Annual average appreciation of a house × 100		12.09 (24.95)	24.68 (49.57)	13.47 (16.24)	6.43 (12.39)
APPBI100	Annual average appreciation of the Boston housing index × 100		6.70 (5.36)	7.37 (2.10)	7.12 (4.77)	6.13 (6.48)
FSTP	Sale price of house in first year of sale		160,468 (101,741)	50,035 (20,856)	106,018 (38,377)	242,891 (85,349)
FSTPSQ	FSTP squared					
AGE	Age of the house in years	21 (33)	18 (31)	26 (41)	17 (34)	16 (24)
AGESQ	AGE squared					
AREA	Living area in square feet	2113 (740)	2107 (726)	1787 (648)	2098 (669)	2231 (762)
LAND	Lot size in square feet	40,195 (36,969)	39,604 (24,628)	37,059 (21,663)	39,262 (22,987)	40,799 (26,850)
DIST	Distance from incinerator in feet	20,268 (9000)	21,435 (9305)	22,353 (9005)	21,972 (8858)	20,685 (9744)
LNDIST	Natural log of DIST					
DUM7980, DUM8184 DUM8588, DUM8992	Dummy variables for phase of incinerator siting (Rumor: 1979–1980, Construction: 1981–1984, Operation: 1985–1988, Adjustment: 1989–1992).					
T	Time trend, 1974–1992.					
*T*7980, *T*8184 *T*8588, *T*8992	Interaction term between *T* and DUM7980, DUM8184, DUM8588, DUM8992.					
LDST7980, LDST8184, LDST8588, LDST8992	Interaction term between log of distance from incinerator with DUM7980, DUM8184, DUM8588, DUM8992.					

($LNDIST*DUM_i = LDST_i$) allow the effect of distance on house prices to vary over time. Only the coefficient during the operation phase (LDST8588) is statistically different from zero.

A time trend (T) and phase indicator variables (DUM_i) are included and are found to be statistically significant. The coefficient on the former is positive and captures both North Andover specific appreciation and the discount rate; the two cannot be separated. The latter variables allow for shifts in the trend.

To test whether appreciation rates vary over the siting process, interaction terms between the time trend and period indicators ($T^*DUM_i = T_i$) are included. If appreciation rates are constant over the periods, the estimated coefficients on these terms should be zero. This is true only for the rumor stage. The coefficients are negative and statistically significant in the other stages; individuals who hold houses during these periods will see a drop both in the value of their home and in the rate at which it appreciates. The appreciation rate falls by 2% during the construction phase, by 3% in the early operation phases and by 3.5% during the ongoing operation. (The interpretation of the coefficient is ($e^{\hat{\beta}} - 1$) which is close to the estimated coefficient for small values of $\hat{\beta}$). These numbers confirm the survey data presented by Greenberg and Hughes [6].

Compensation programs need to be designed to include both the decline in value and in appreciation rates, if they are to correctly capture the cost of the incinerator. (For a theoretical approach to designing compensation programs see Mitchell and Carson [13]). Figure 1 shows the actual average sales prices of houses in the sample, adjusted by the Boston index. This series does not control for the changes in characteristics of houses sold, such as an increase in quality. Also plotted is the log of predicted sales price of the "average" sample house, calculated using the estimated coefficients from Table 2. This house is 21 years old, has 2113 square feet of living space, sits on 40,195 square feet of land, and is located one-half mile from the incinerator. This line follows the pattern of the actual sales prices quite well, but lies below that line since it represents a constant quality house.

The third line is a "naive" prediction of sales prices based on data from two periods, one before and one after the incinerator went on line. Regressions were estimated for sales in the 1980–1981 period, while the incinerator was still a rumor, and for the 1986–1987 period when the plant was in operation. The sales price for the average sample house was then predicted for those two periods using the estimated coefficients; the drop reveals the decline in values due to the incinerator. The rate at which these two prices were appreciated over time, 7.545%, was calculated from the actual average sales prices between 1980 and 1981. This rate was held constant over the entire period as studies that have focused only on values

TABLE 2
Estimation Results

Dependent Variable: LNPBI Number of Observations: 2593	
CONST	−71.235**
	(−4.55)
AGE	−0.90729E-02**
	(−21.50)
AGESQ	0.38999E-04**
	(15.62)
AREA	0.26850E-03**
	(32.28)
LAND	0.70867E-06**
	(4.48)
LNDIST	0.06557**
	(2.77)
LDST7980	−0.90414E-02
	(−0.23)
LDST8184	−0.02208
	(−0.73)
LDST8588	−0.05073*
	(−1.74)
LDST8992	−0.05940
	(−1.60)
DUM7980	8.7916
	(0.13)
DUM8184	40.782
	(1.66)
DUM8588	59.104**
	(2.40)
DUM8992	69.638**
	(2.22)
T	0.03786**
	(4.77)
*T*7980	−0.43791E-02
	(−0.13)
*T*8184	−0.02047
	(−1.65)
*T*8588	−0.02958**
	(−2.38)
*T*8992	−0.03488**
	(−2.21)
SSR	188.54
R^2	0.610
Adj. R^2	0.607
F-statistic	223.33
LLF	−280.24

Note. Values in parentheses are *t*-statistics.
*Significant at $\alpha = 0.10$.
**Significant at $\alpha = 0.05$.

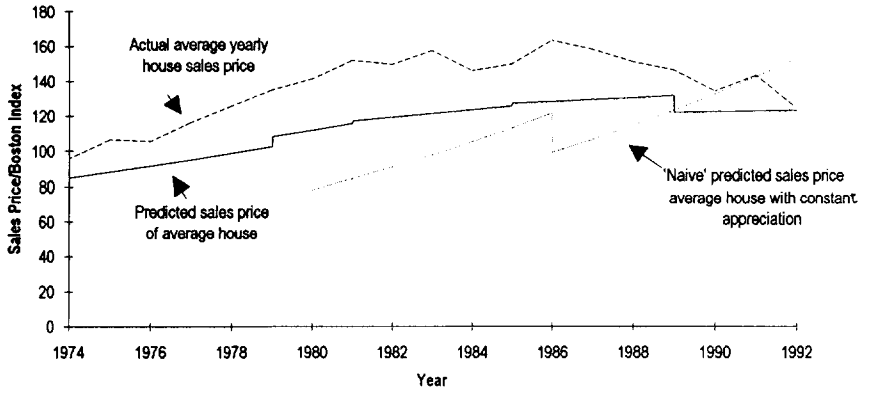

FIGURE 1

have implicitly done. The graph indicates that such a technique would greatly understate the effect of the incinerator on prices.

V. ESTIMATION OF APPRECIATION RATES USING REPEAT SALES

In estimating the model using repeat sales data, only houses that sold twice during a phase, but not twice in one year, are included. Because this eliminated so many houses from the sample, the five phases are reduced to three: 1974–1978 as the first, or normal, stage; 1979–1984 as the rumor and construction phase, where uncertainty exists about whether the incinerator will go on line and if it does how much damage it will cause; and 1985–1992 as the final stage, where uncertainty about damage decreases as information is gained through experience, and the market adjusts toward a stable equilibrium. The sample size is 310.

Once annual appreciation rates are calculated for each house using Eq. (4), regressions are estimated using the individual housing appreciation rates multiplied by 100 as the dependent variable (APP100), housing characteristics (including distance from the incinerator), and neighborhood characteristics. The means, standard deviations, and definitions of each variable can be found in Table 1, Columns 2–5.

The model was first estimated on the entire sample of repeat sales. This approach restricts the contribution of characteristics, other than distance, to the appreciation rate to be constant over the entire period. The model was statistically rejected in favor of an unrestricted model. Table 3 shows the results of the three separate phase regressions of the unrestricted model. In phase one (column 1), 53 houses sold twice between 1974 and

TABLE 3
Estimation Results for Repeated Sales Approach

	Dependent Variable: APP100		
	Stage 1 1974–1978	Stage 2 1979–1984	Stage 3 1985–1992
Number of observations	53	112	145
CONSTANT	69.28	19.67	−0.04
	(0.43)	(0.66)	(−0.28E-02)
APPBI100	5.58**	0.79**	1.22**
	(2.11)	(3.35)	(10.36)
FSTP	−0.62E-02**	−0.78E-03**	−0.21E-03**
	(−4.57)	(−5.25)	(−3.85)
FSTPSQ	0.39E-07**	0.20E-08**	0.23E-09**
	(3.33)	(3.21)	(2.53)
AGE	−1.41**	−0.04	−0.19*
	(−2.15)	(−0.30)	(−1.66)
AGESQ	0.71E-02	−0.24E-03	0.15E-02
	(1.96)	(−0.30)	(1.53)
AREA	0.02**	0.02**	0.52**
	(2.35)	(8.10)	(2.64)
LAND	−0.61	0.12E-04	−0.43E-04
	(−0.17)	(0.19)	(−1.47)
LNDIST	8.82	0.55	2.60**
	(0.58)	(0.19)	(2.18)
SSR	61,685	13,649	7727.9
R^2	.517	.534	.650
Adj. R^2	.429	.497	.630
F-stat	5.89	14.73	31.63
LLF	−262.28	−427.89	−494.00

Note. Values in parentheses are t-statistics.
*Significant at $\alpha = 0.10$.
**Significant at $\alpha = 0.05$.

1978. The coefficient on Boston's appreciation rate during those years (APPB100—calculated using the National Association of Realtors' median house price index and multiplied by 100) is statistically significant. The housing characteristic variables chosen are similar to those used by Kiel and Carson [7]. The price of the house at the time of the first sale (FSTP) and the square of that variable (FSTPSQ) are both significant, indicating that lower and higher priced homes (in terms of the first-sale value) experienced higher appreciation rates than those in the middle range. The coefficient on the log of distance from the house to the incinerator (LNDIST) is not statistically different from zero during the normal phase. Being located close to the land where the incinerator was sited does not appear to have had a negative impact on appreciation rates prior to the siting.

Column 2 gives the results for the same model estimated for the 112 houses that had sold twice during the rumor and construction phase from 1979 until 1984. The results are very similar, although the age of the house is no longer statistically significant. The log of the distance is not significant, indicating that rumors of the siting and the construction of the plant did not affect appreciation rates.

The estimation results from the 145 pairs of sales during the operation phase are quite different (Table 3, column 3). The age of the house is marginally significant. The log of distance from the incinerator is now statistically significant, indicating that as distance increases, the rate of appreciation experienced by houses also increases. Thus while the rumors and construction of the plant did not affect rates, operation of the facility did. In the capitalization model, the construction phase also affected rates. It is possible that if enough repeat sales data existed to separate the rumor and construction phases, similar results may have been obtained.

VI. CONCLUSIONS

Individual housing appreciation rates are affected by the presence of an incinerator. Using the log of house sales prices and adjusting for appreciation in nearby Boston, appreciation rates in North Andover fall during the construction and operation phases of the siting process. Distance from the incinerator plays an important role. When repeat sales are used to calculate appreciation rates, the positive effect of distance is revealed only when the facility is in operation, although a more extensive data set might reveal a similar impact in the construction phase.

These findings suggest that when the full cost of the siting and operation of a locally undesirable facility is estimated, both the short-run and long-run impacts need to be considered. A drop in house values may take place as early as the first rumors of the facility, and levels may again be affected as more information on the facility becomes available. The observed differences in appreciation rates experienced by houses close to the incinerator and those farther away, which continue to differ after the facility has gone on line, indicate that the local housing market has not fully adjusted to the facility, even after 7 years of operation. If the designers of compensation programs want to correctly measure the decline in property values experienced by those located close to such a facility, measurements of the changes in levels must be taken at each of the stages as well as after the facility has gone into operation.

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