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House Prices during Siting Decision Stages: The Case of an Incinerator from Rumor through Operation[1]

KATHERINE A. KIEL

Northeastern University, Boston, Massachusetts 02115

AND

KATHERINE T. MCCLAIN

Pennsylvania State University, University Park, Pennsylvania 16802

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The impact of an undesirable land use on house prices is not constant over time. Previous proximity studies which employed only discrete changes in information, such as an EPA Superfund site announcement, ignored potentially important phases of the adjustment process. This study explicitly measures how the effects of an undesirable land use evolve over the siting process and life of the disamenity. Some price response to rumors of a facility is indicated, and the evidence that prices respond at groundbreaking, before operation, is strong. The distance premium persists at least 7 years after the facility begins operations. © 1995 Academic Press, Inc.

I. INTRODUCTION

Locally unwanted land uses take many forms. Some are hazardous, others are merely undesirable neighbors. Public opposition to both is growing. They often serve a large segment of the population but adversely affect only a small local area and population, whose residents are asked to shoulder the risks and costs of a project while the benefits accrue to the larger public. The volume and vociferousness of community opposition to the siting of unwanted facilities suggests that residents are implicitly calculating an individual cost/benefit analysis and concluding that the local, concentrated costs associated with the facility outweigh the dispersed benefits, including an individual estimate of the social welfare impact of the facility.[2]

Some of the most vocal opposition comes from homeowners. A house is one of the largest investments a household will ever make, and anything which influences the price and/or appreciation rate of that house will also affect investment

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[2]Portney [12] reports the results of a telephone survey which illustrates that residents mentally estimate a cost/benefit analysis when asked whether they favor construction of a hazardous waste treatment facility. The study also reveals that while individuals recognize the need for and benefits associated with a facility to society as a whole, they do not necessarily want to bear the costs of such a facility locally.

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portfolios and future security. A decline in residential real estate values in the proximity of an undesirable facility is well-documented (e.g., [6, 3, 8]).

This study is explicitly designed to measure how the effects of a disamenity on residential property values evolve over the siting process and life of the disamenity. An important similarity of previous proximity studies is their use of a single event, such as the impact of an announcement by the EPA concerning the safety of a dump, or the effect of a major accident at a nuclear power plant, without measuring the effect of the original siting of the facility or controlling for any market responses to earlier information. The impact of an undesirable facility is unlikely to be constant over time and information is lost if potentially important phases of the adjustment process are ignored.

Individuals concerned with the potential health effects of a nearby landfill or who place a high probability on a nuclear accident occurring may have moved from an area prior to the sample period chosen, perhaps even when construction of a facility was first proposed. The restriction of previous studies to a moment in time before a significant event and a moment in time after the event may understate the true cost of the undesirable facility location. Additionally, the effect of a facility on house values may change over time as neighbors acquire more information, good or bad, on the aesthetic and health consequences of the facility.

In a comment on the study by Gamble and Downing, Galster [2] concurs, although without any empirical evidence, stating that "households begin adjusting when they first hear a public announcement of the location of a forthcoming nuclear power plant"(p. 804). The uncertainty surrounding the project—whether and where the facility is located and how undesirable the facility might be—will change through time and should be reflected in the prices of houses. The approach of this study leads to a more complete estimate of the impact of the plant on house values, and to a better understanding of the market adjustment process.

The social welfare loss associated with housing value declines from a facility could be completely measured using only two points in time, but only if those two points are carefully chosen, one before any price adjustment begins and the other after adjustment is complete. Those points may be difficult to correctly identify if the siting life cycle is overly simplified or ignored and the total welfare loss then poorly estimated. Furthermore, ignoring the profile of changes in social welfare over the siting of the facility could result in over- or undercompensation of individuals if there have been several transfers of ownership during this period.

Finally, if after adjustment is complete the facility is regarded as innocuous, prices will rebound and the total change in social welfare will be zero. In this case, however, a substantial transfer of welfare may have occurred from buyers to sellers. For example, if a house was sold during a phase when fears of the facility depressed prices, the seller would suffer a capital loss. If those fears are later unrealized and prices rebound, that loss becomes the buyer's gain, but the net effect on social welfare will be zero. Whether this sort of transfer should be compensated must be decided on an equity rather than an efficiency basis.

II. PREVIOUS FINDINGS AND THEORETICAL MODEL

Many studies have investigated the effect of a hazardous or undesirable facility on nearby real estate. Conventional theory holds that the value of a house is determined by its characteristics, including neighborhood amenities or disamenities; thus proximity to an undesirable facility should be reflected by a price which is lower than that of an identical house that is not near such a facility.

Gamble and Downing [3], in a study of house values around Three Mile Island before the accident (1977–1979) and after (the last 9 months of 1979), found that increased distance from the plant did increase the value of the house. The facility had gone on-line in the early 1970s, but the study made no attempt to account for house price adjustments attributable solely to the presence of the plant before the accident.

Twark *et al.* [15] also examined Three Mile Island. They ran three regressions on sales prices (1977–1979, 1980–1981, and 1986) and found that the coefficients on distance differed in each regression and that houses 0–2 miles from the plant fell in value after the accident in 1979 but had rebounded by 1986. Again, no attempt was made to estimate adjustments made prior to the accident.

Kohlhase [6] studied toxic dumps in Houston in 1976, 1980, and 1986. These periods represent years when (i) the site was in operation but before EPA announcements about its safety, (ii) the EPA was making announcements about other sites, and (iii) after the EPA had made an announcement about the site itself. She found that distance from the dumps displayed the "correct" sign and was statistically significant only in 1986—after the EPA had announced that the sites were toxic, although the sites had been in operation since the 1960 and 1970s. Neighbors may have adjusted to the dumps prior to 1976 and the price movements Kohlhase observed may have been a response to new information.

Michaels and Smith [8] examined toxic sites in Boston using data from 1977 through 1981. The sites had been identified as dangerous in 1978, 1979, or 1980, with one exception which was previously "discovered" in 1967. The authors found that distance does affect prices and that the effect increases 6 months after the announcement by the EPA, illustrating that individuals do respond to new information.

One shortcoming of these approaches is that the impact of an undesirable facility on house prices is unlikely to be constant over time and should not be relegated to a one-time price adjustment. Assuming market-clearing rents, the asset price of a house is the sum of discounted expected future rents [11]. In discreet form,

$$V(t) = \sum_{t=1}^{T} \frac{R_t}{(1+r)^t},$$

where V is the asset price, R_t is rent in year t, r is the discount rate, and T is the life of the dwelling. While current rents are unlikely to be affected by the rumor or construction of a facility, if the facility is perceived as a negative externality, rents will fall once the unit comes on-line. If evidence later accumulates that the plant is not harmful or disruptive, rent should rebound.

The relationship between the fall in rents and a corresponding decline in house values depends upon what assumptions are made about expectations. If a fall in rents due to a facility going on-line is perfectly forecast by all neighbors when the plant is initially rumored or proposed, then value will begin to decline as early as the rumor stage. Value will continue to decline until all future rents have responded to the presence of the externality. Adjustment should be complete by the start of operations. The extent of the decline in values will depend on the decline in rents and on discount rates.

In the case where information is not available to all neighbors, or where there is uncertainty about whether or when the facility will go on-line, the adjustment process may take longer. In such a situation, if all individuals have the same tastes, then those who place a higher probability on the actual operation of the facility may choose to move, selling their home to individuals who place a lower probability on the operation. The latter are willing to purchase if the expected damages are less than the expected benefits from the new home, in their estimation. If tastes as well as expectations differ, sales can also take place between those who dislike living near the facility and those who are willing to locate near it given a house price that compensates them for doing so.

Using a large dataset which extends over 19 years, this study is an effort to more systematically measure the effect over time of an undesirable facility on house prices. This is achieved by dividing the siting, construction, and operation of a facility into five stages, each associated with a different level of risk as perceived by neighbors. Stage one is the pre-rumor stage, which takes place before any mention of the possibility of an undesirable land use. Real estate values during this period should reflect the supply and demand of housing and the various characteristics of the structure, neighborhood, and community.

The rumor, or second stage, begins once news of the proposed project leaks or is announced to the community. Uncertainty arises in the form of whether and where the facility will be located and how dangerous or disruptive the facility will be. This uncertainty should be reflected in the real estate market in the form of lower prices or longer listing periods, and homeowner concerns of property value loss are frequently voiced at this time. Says a homeowner in the neighborhood of a proposed limestone mine [9, p. 1]:

> But now that people know there's probably going to be some kind of mining operation next door, nobody is interested in buying unless it's a real bargain—far below what it was worth before this happened.... [The company] says property values won't be decreased by a mine in the neighborhood, but we know better.

This homeowner goes on to tell of a neighbor who "sold his home for much less than it was worth because he was afraid that if he waited, nobody would buy it at all," (p. 1) even though at the time the mine was only *proposed* and no permits had yet been granted. Households which assign a high probability to a facility going on-line and/or which expect to suffer a great deal from the arrival of the facility are likely to try to move out, even if they "take a loss" on their unit.

The third stage, construction, begins when permitting is final and construction of the facility is undertaken. During this stage the probability of the plant is taken to be one,[3] so a mobility decision will be based on expected damages relative to expected moving costs and future property losses.

The fourth stage commences when the facility goes on-line. Knowledge of the environmental and health effects of the facility will accumulate over this period until no more uncertainty about the effects exist. Thus, damage should be measur-

[3]Although some facilities have been successfully blocked or substantially delayed by local opposition even after construction was begun, we implicitly have assumed that most residents become resigned to the reality of a facility once ground is broken and behave accordingly.

able as an actual figure rather than an expected value. As this knowledge moves through the market, prices should make their final adjustment.

The fifth, or ongoing operations stage, is a return to "normal" conditions and should be similar to the first stage with prices determined by the supply and demand for housing, given the changes in the neighborhood. If the presence of the facility is perceived as a disamenity, the equilibrium price of a house should be lower, after adjusting for inflation, than it was in the first stage. Interestingly, even if evidence reveals that the facility is benign, recent research has revealed that initial risk perceptions may persist because of the way new information is interpreted. New information which is consistent with an individual's existing beliefs is accepted as reliable and accurate, while conflicting information is labeled erroneous, unrepresentative, or propaganda [14]. Any downward pressure on prices could be quite prolonged.

The movement of prices through time will be measured using hedonic regression models, which have successfully been applied to housing data for some time.[4] Each of the various characteristics of the house and its location individually contribute to the value of a house, and a partial derivative of the price of a house with respect to any one characteristic should provide a measure of that contribution.

III. DATA

The dataset compiled for this study consists of 2593 single-family home sales in North Andover, Massachusetts, from January 1974 through May 1992. North Andover is located approximately 20 miles north of Boston near several major highways and has a total area of 27.85 square miles. Only houses within North Andover are considered because tax treatment, city services, and host benefits are unique to the town.

As the town's landfill moved toward capacity in the late 1970s, an incinerator which would turn refuse into electricity was proposed. First mention of the facility in the North Andover *Citizen* was in 1978. The facility is located in the northwest corner of the town.

The waste-to-energy incinerator proposed included an electrostatic precipitator to clean the emissions and meet all environmental standards. Regardless, articles in the local paper at the time the facility was proposed discussed the "environmental soundness of the plant" (September 14, 1978), as well as the possibility that the plant would present "a health threat to those living near the plant" (October 2, 1978). These fears might have been well-founded as the *Citizen* later reported that North Andover had the "second highest level of total cancer-causing air emissions in the state for 1988 ... and the third highest level of birth defect-causing chemicals for 1988 ..." (June 19, 1991). The emissions from similar facilities (including the incinerator in Saugus, Massachusetts) have been studied and are discussed by Hjelmar *et al.* [4].

A contract was signed with the facility provider early in 1981. After much uncertainty about funding, groundbreaking for the plant took place in 1983, and the plant went on line in 1985.

[4] Rothenberg *et al.* [13, Chap. 3] provide a good overview of hedonic models.

Based on this information, the five siting stages for this study have been defined as

Pre-rumor	1974–1978
Rumor	1979–1980
Construction	1981–1984
Online	1985–1988
Ongoing Operation	1989–1992.

Although the first mention of the plant occurred in 1978, it was late in the year, and some time must elapse for such information to become widespread. Therefore, data from 1978 was assigned to the pre-rumor stage and 1979 data to the rumor stage. Estimation results support this choice. The choice on where to separate the early operation stage and the ongoing operation stage was more abstract, but 4 years was considered sufficient time for local residents to become aware of the advantages and disadvantages of living near the incinerator.

The data, collected from the North Andover tax assessor's office, contains structural information about each house, including the number of bedrooms, baths, floor space, the age of the house, and the area of the lot of land on which it is located. The minimum and maximum distance between the incinerator and a house are 3500 and 40,000 feet, respectively. Information added by the researchers includes whether the house is located in a lakefront neighborhood and its distance from the incinerator, the entrance to a major highway, and the central business district. Distance is measured by a straight line from the center of each lot to each of the above. Information on occupants of the house could not be obtained , but as Butler [1] has pointed out, "augmenting the list of independent variables with such demander characteristics as *income*... *is a clear misspecification*" (p. 96). The

TABLE I
Variable Descriptions

Name	Description
SALES PRICE	Nominal transaction price of house
BOSTON INDEX	Nominal median price of existing single family homes for the Boston MSA in hundreds of dollars
PBI	House sales price divided by Boston house price index
AGE	Age of the house in years
AREA	Living area in square feet
BATH	Number of bathrooms
ROOM	Number of rooms
LAND	Lot size in square feet
DIST	Distance from incinerator in feet
INTST	Distance from house to interstate entrance ramp in feet
LAKE	Dummy variable for homes close to lake
CBD	Distance from house to central business district in feet
DUM7980, DUM8184, DUM8588, DUM8992	Incinerator phase dummy variables (Rumor, 1979–1980; Construction, 1981–1984; Online Operation, 1985–1988; Ongoing Operation, 1989–1992)
LDST7980, LDST8184 LDST8588, LDST8992	Interaction term between log of distance from incinerator and incinerator phase dummy variables

TABLE II

Data Sample Statistics: Mean (Standard Deviation)

	Total period	Prerumor$_a$ 1974–1977	Rumor$_a$ 1978–1980	Prerumor$_b$ 1974–1978	Rumor$_b$ 1979–1980	Construction 1981–1984	Online 1985–1988	Ongoing 1989–1992
No. of Obs.	2593	416	481	595	302	662	711	323
PBI	140.73	107.53	133.21	112.97	137.71	151.69	156.29	137.94
	(57.01)	(45.91)	(50.50)	(47.92)	(50.21)	(57.68)	(60.22)	(50.18)
AGE	21	24	20	23	19	19	20	27
	(33)	(37)	(35)	(38)	(34)	(29)	(32)	(33)
AREA	2113	1839	2020	1887	2032	2146	2234	2268
	(740)	(680)	(625)	(670)	(619)	(661)	(828)	(806)
BATH	2.01	1.78	2.01	1.85	2.02	2.05	2.11	2.01
	(0.65)	(0.63)	(0.63)	(0.64)	(0.63)	(0.63)	(0.65)	(0.67)
ROOM	6.63	6.56	6.57	6.56	6.56	6.72	6.65	6.58
	1.00	(1.29)	(0.94)	(1.20)	(0.93)	(0.95)	(0.94)	(0.87)
LAND	40195	37188	39320	38923	37165	39402	41130	44940
	(36969)	(32911)	(37540)	(38996)	(27224)	37317	29723	51570
DIST	20268	19720	21013	20164	20905	20181	19975	20690
	(9000)	(8961)	(9137)	(8946)	(9316)	(8876)	(9050)	(8953)
LNINTST	9.45	9.30	9.46	9.36	9.44	9.46	9.50	9.47
	(0.81)	(0.88)	(0.82)	(0.87)	(0.82)	(0.78)	(0.77)	(0.81)
LAKE	0.101	0.067	0.079	0.072	0.076	0.113	0.117	0.108
	(0.301)	(0.251)	(0.270)	(0.259)	(0.266)	(0.321)	(0.321)	(0.311)
SALES PRICE	157841	55639	88266	61953	95163	130929	251423	242242
	(104495)	(24915)	(34648)	(28418)	(35092)	(50415)	(102836)	(89853)
BOSTON INDEX	1085.11	515.09	660.40	543.64	690.27	864.93	1607.01	1754.20
	(490.13)	(36.40)	(47.14)	(53.14)	(33.73)	(86.32)	(180.18)	(49.29)
INTST	16206	14736	16674	15455	16404	16201	16565	16622
	(9249)	(9444)	(9782)	(9494)	(9993)	(9137)	(8820)	(9197)
CBD	15476	14291	16019	14933	15778	15458	15613	15926
	(9257)	(9392)	(9754)	(9441)	(9959)	(9060)	(8997)	(9208)
MIN DISTANCE	3500							
MAX DISTANCE	40000							

variable definitions may be found in Table I, and the means and standard deviations of the variables are presented in Table II.

North Andover is a very homogeneous town which has not changed greatly over time. Data from the the 1960, 1970, 1980, and preliminary 1990 National Census reveal that the population of North Andover was 99% white until 1990, when it dropped to 97%. The population has grown from 10,980 in 1960 to 16,247 in 1970; 20,129 in 1980 to 22,792 in 1990. The median levels of education have changed very little over the period in question. The town has a single school district with four elementary schools, one middle school, and one high school.

Prices are adjusted to control for the regional trend in sales prices over the period. The dependent variable used throughout is the natural log of the sales price in current dollars divided by an index based on the median sales price of existing single-family homes in the Boston MSA (also in current dollars; data from the National Board of Realtors series *Homes Sales*, published monthly, and Karl Case, private communication). The housing price boom in Boston during the 1980s was undoubtedly reflected in the North Andover market, and the dependent variable chosen should account for both the general inflation and the acceleration that was unique to the greater Boston area.

IV. ESTIMATION RESULTS

The model can be estimated in two ways. A separate regression for each of the five stages can be estimated, similar to the earlier studies of Kohlhase [6] and

Gamble and Downing [3]. Alternatively, the model can be estimated over the entire sample with interaction terms of distance and time period indicators to measure the changing impact of the incinerator. This fixed-effects technique [5] allows for correlation between the unobserved and observed effects and is appropriate when some features through time are not observable but presumed constant across houses.[5]

The general form of the model is

$$\ln\left(\frac{\mathrm{P}}{\mathrm{BI}}\right)_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 f(\mathrm{DIST})_i + \varepsilon_i,$$

where i indexes the house, X_1 is a vector of structural characteristics; X_2 a vector of neighborhood characteristics, and f(DIST) a function of the distance from the house to the incinerator. Previous studies have employed a variety of functional forms for distance including quadratic and concentric zones (e.g., Kohlhase [6], Mendelsohn *et al.* [7]). The natural log of distance selected for this study allows the effect of the incinerator to decrease at a decreasing rate, yet increasing distance is always advantageous.[6]

Consider the regression estimates from the individual phase regressions (Table III). The structural characteristics are generally significant with the expected sign over all time periods. A quadratic function of the distance from the major interstate artery into Boston, a neighborhood characteristic, was chosen because living close to a highway ramp means heavy traffic and noise, but living far from it is inconvenient. (This variable is significant with the correct sign in all but the earliest years of the sample, perhaps because in the early 1970s the suburban Boston area was less congested and travel by secondary roads was as convenient as the highway.) LAKE, intended to capture the effect of an upscale waterfront housing development midway through the sample, did not prove useful. Other neighborhood variables were considered in preliminary specifications but were dropped because they were statistically insignificant and did not add to the explanatory power of the model. They were the distance to the central business district, which was collinear with the distance to the interstate highway, and a variable which measured the percentage of time the wind blew from the incinerator toward the house. The results from WIND were disappointing, possibly because it was based on wind measurements from Boston's seaside Logan Airport, while North Andover is inland.

The coefficient on LNDIST measures the impact of the incinerator on house prices. The coefficient is not significant in the pre-rumor stage, suggesting that the eventual site of the plant was not inherently undesirable before it was selected for the incinerator. The coefficient was also not significant in the rumor stage, regardless of whether 1978 or 1979 is chosen as the first year of this stage. House prices apparently did not respond to the negative publicity the proposed facility was receiving and the public opposition voiced. Most of the debate appeared in the

[5] A third alternative would be a repeat sales approach, but the number of within period repeat sales is insufficient to allow all five periods to be estimated.

[6] For comparison, a quadratic form was estimated, but the fit was not improved and the coefficients implied that being far from the facility was not more advantageous than being very close.

TABLE III

Regression Estimates by Individual Phase Regressions

	$Prerumor_a$ 1974–1977	$Rumor_a$ 1978–1980	$Prerumor_b$ 1974–1978	$Rumor_b$ 1979–1980	Construction 1981–1984	Online 1986–1988	Ongoing 1989–1992
CONST	3.59**	3.47**	3.54**	3.79**	3.29**	2.72**	3.06**
	(5.29)	(7.46)	(6.86)	(5.84)	(9.73)	(8.18)	(9.26)
AGE	−0.79E-02**	−0.76E-02**	−0.79E-02**	−0.71E-02**	−0.58E-02**	−0.29E-02**	−0.65E-02**
	(−5.59)	(−7.41)	(−7.06)	(−5.50)	(−5.35)	(−3.11)	(−6.90)
AGESQ	0.33E-04**	0.29E-04**	0.33E-04**	0.27E-04**	0.27E-04**	0.89E-05**	0.31E-04**
	(4.71)	(5.21)	(5.74)	(4.01)	(3.74)	(1.78)	(6.08)
AREA	0.10E-03**	0.22E-03**	0.14E-03**	0.21E-03**	0.18E-03**	0.18E-03**	0.17E-03**
	(3.05)	(8.33)	(5.11)	(5.56)	(8.95)	(10.27)	(10.63)
BATH	0.14**	0.08**	0.14**	0.08**	0.22**	0.16**	0.15**
	(3.37)	(2.91)	(4.27)	(1.97)	(8.38)	(5.99)	(5.72)
ROOM	0.07**	0.05**	0.07**	0.04**	0.01	0.05**	0.02
	(4.23)	(2.79)	(4.88)	(1.87)	(1.01)	(3.81)	(1.24)
LAND	0.17E-05**	0.44E-06	0.13E-05**	0.32E-06	0.55E-07	0.35E-06	0.15E-06
	(2.67)	(1.25)	(3.23)	(0.43)	(0.19)	(0.92)	(0.74)
LN DIST	0.014	0.042	0.020	0.743E-02	0.071*	0.122**	0.107**
	(0.19)	(0.82)	(0.36)	(0.10)	(1.95)	(3.30)	(3.03)
INTST	0.43E-05	0.16E-04**	0.57E-05	0.28E-04**	0.22E-04**	0.12E-04**	0.17E-04**
	(0.41)	(2.39)	(0.73)	(2.85)	(3.83)	(1.99)	(3.31)
INTSTSQ	0.16E-09	−0.49E-09**	−0.19E-09	−0.74E-09**	−0.73E-09**	−0.47E-09**	−0.64E-09**
	(−0.58)	(−3.07)	(−0.95)	(−3.33)	(−5.03)	(−3.33)	(−5.18)
LAKE	−0.17**	0.07	−0.12**	0.09	0.17E-02	0.10**	0.04
	(−2.11)	(1.53)	(−2.09)	(1.48)	(0.04)	(2.54)	(1.03)
Sample Size	416	481	595	302	662	711	323
$AdjR^2$	0.392	0.611	0.459	0.585	0.675	0.680	0.794
LLF	−162.50	−5.72	−174.60	−21.97	36.73	34.304	131.27

Note. Numbers in parentheses are t statistics. Dependent variable: LN (Sale Price/Boston Index).

*Significant at 10%.

**Significant at 5%.

local newspaper rather than the more widely circulated Boston *Globe*, and potential homeowners from outside of North Andover (perhaps the majority of purchasers) may have been unaware of the proposal to construct an incinerator. Alternatively, public consensus may have been that the plant would never become a reality (many proposed undesirable facilities are never built) or that the eventual undesirable effects of the plant were underestimated or underpublicized.

By the time construction began, however, houses further from the site received a premium. The presence of an incinerator could no longer be denied or hidden from potential buyers. Not only was information about the undesirable attributes of waste incineration becoming more available and widespread, but it is also possible that the increased traffic of heavy construction vehicles may have provided a foretaste of the constant stream of large garbage trucks which would eventually appear.

The marginal impact of distance on the value of a house in North Andover during this phase can be calculated by multiplying the coefficient on LNDIST by the ratio of the dependent variable and DIST when evaluated at the means. The value obtained, 0.0005, can then be multiplied by the mean value of BI, resulting in a change in the nominal sales price of \$0.43 per foot, or \$2283 per mile. Kohlhase [6] found the impact of an EPA announcement of a superfund site to be higher, at \$3310 per mile. The premium paid for distance persisted through the early operating years, when information about living near an incinerator would be

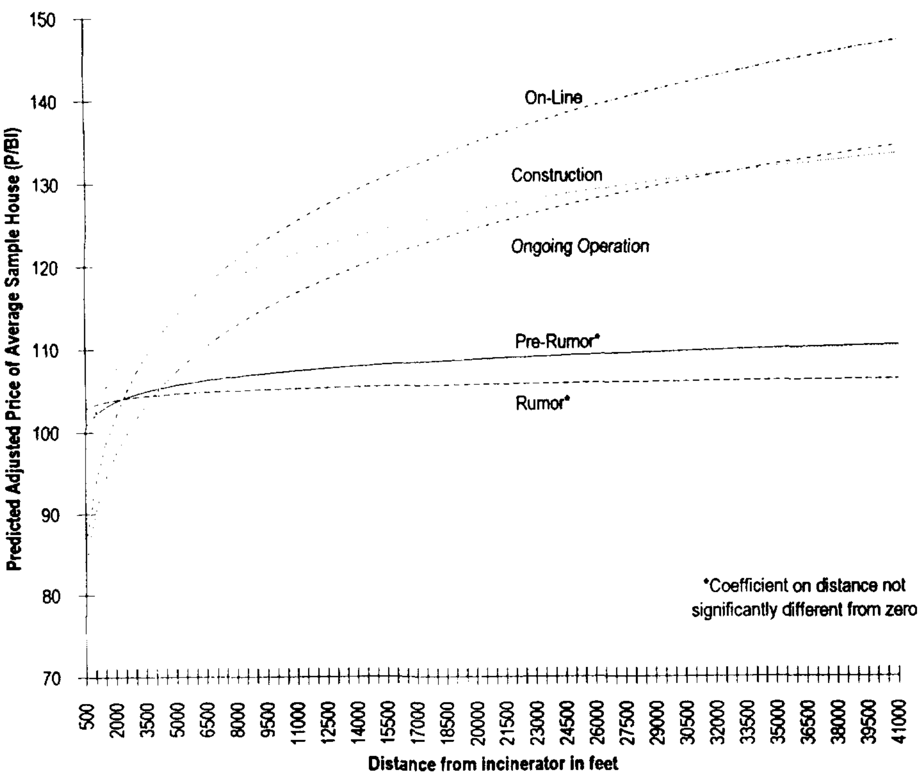

FIG. 1. Effect of distance on predicted house price from individual phase regressions.

acquired. The premium calculated for this period is $8100 per mile, substantially more than Kohlhase's estimate. The annual change in the premium over the prior phase is 37% while housing inflation in Boston between 1982 and 1986 was only 18.7% (calculated using the Boston index employed earlier in the paper).

By 1989, 4 years after the plant went into operation, sufficient evidence about the incinerator's impact on residential life should have accumulated. Distance should no longer be significant if resident's fears were unfounded or new buyers were indifferent to the facility. However, the coefficient on distance remains significant and positive. The premium during this period was $6607 per mile, a decrease over the online period, but still larger than the construction phase. The persistence of a premium indicates that either the incinerator is viewed as a permanent diamenity or full adjustment takes longer than previously thought.

TABLE IV

Regression Estimates from Pooled Data

CONST	3.25**
	(17.44)
AGE	−0.59E-02**
	(−12.60)
AGESQ	0.25E-04**
	(9.51)
AREA	0.16E-03**
	(16.24)
BATH	0.15**
	(11.18)
ROOM	0.04**
	(6.69)
LAND	0.44E-06**
	(2.72)
LNDIST	0.053**
	(2.61)
LDST7980	0.015**
	(8.24)
LDST8184	0.022**
	(14.54)
LDST8588	0.023**
	(15.28)
LDST8992	0.016**
	(8.40)
INTST	0.16E-04**
	(5.21)
INTSQ	−0.54E-09**
	(−7.12)
LAKE	0.02
	(0.79)
AdjR^2	0.646
LLF	−146.44

Note. Numbers in parentheses are *t* statistics. Dependent variable: LN(Sales Price/Boston Index). Sample size: 2593.

*Significant at 10%.

**Significant at 5%.

Figure 1 illustrates the relationship between price, distance, and phase. The vertical axis is the predicted price of the average sample house from each of the five regressions in Table III.[7] The nearly horizontal lines for the pre-rumor and rumor phases show that prior to the incinerator, distance did not impact on price. The sharply ascending lines for the remaining three phases, especially over the first 2 miles, illustrate the positive premium being paid to live further away. The figure also indicates a shift in demand from houses nearer the incinerator to those further away over the time period sampled. Within three-quarters of a mile from the plant, demand dropped and predicted price is lower than before the incinerator existed. Demand for houses more than three-quarters of a mile went up, pushing prices in these areas above their pre-incinerator values. The shift is most pronounced during the on-line phase, but persists during ongoing operation. Because of the double log regression, no maximum distance effect can be computed, but this graph can provide some approximation of this effect. As the lines flatten, the benefits of increasing distance to the value of the house become less substantial. For the last three phases, this point begins at approximately 20,000 feet (3.5 miles).

In addition to unraveling the complex adjustment of prices to the presence of an undesirable facility, the identification and analysis of the separate phases also reveals further evidence on the existence of negative externality impacts. Including the distance between the house and site in the pre-rumor and rumor period acts as a control on the future site of the incinerator. That this variable is not significant during these periods but is significant afterwards further confirms that the incinerator is viewed as a negative externality.

Table IV provides the results from the pooled regression. The LDST variables are interaction terms between the natural log of distance and the siting phases. This method allows the contribution of the structural and neighborhood characteristics to house price to be constant over the entire time period but the effect of distance from the facility to change. As before, in general these characteristics are significant with the appropriate sign. The interaction terms are all significant and positive, suggesting that houses further from the incinerator commanded a premium, even in the rumor phase. Figure 2 again indicates that this effect is most sharply felt during the construction and on-line phases, when the graphed lines are steepest. The shift in demand from nearby to distant houses is not revealed in this figure.[8]

The second method, which holds the contributions of the house's characteristics constant over time, is a restricted version of the first method, where those contributions can change over time. An F-test rejects the restricted form, the

[7]The coefficients from Pre-rumor$_b$ and Rumor$_b$ are used. The average sample house is 21 years old with 2113 square feet of living space, 2.01 baths, 6.63 rooms on 40,195 square feet of land and is not on the lake.

[8]An F-test on the distance coefficients in Table IV rejected the null hypothesis of coefficient stability. A test of the same null did not reject for the distance coefficients in Table III. However, the distance coefficients in the early phases are clearly not statistically different from zero, while the coefficients in the later phases are very statistically significant. While the test may fail to reject the null because it is true, it is also possible that the imprecise estimates of the early coefficients, as indicated by their relatively large standard errors, add significant noise to the test, and the test may be committing a Type II error.

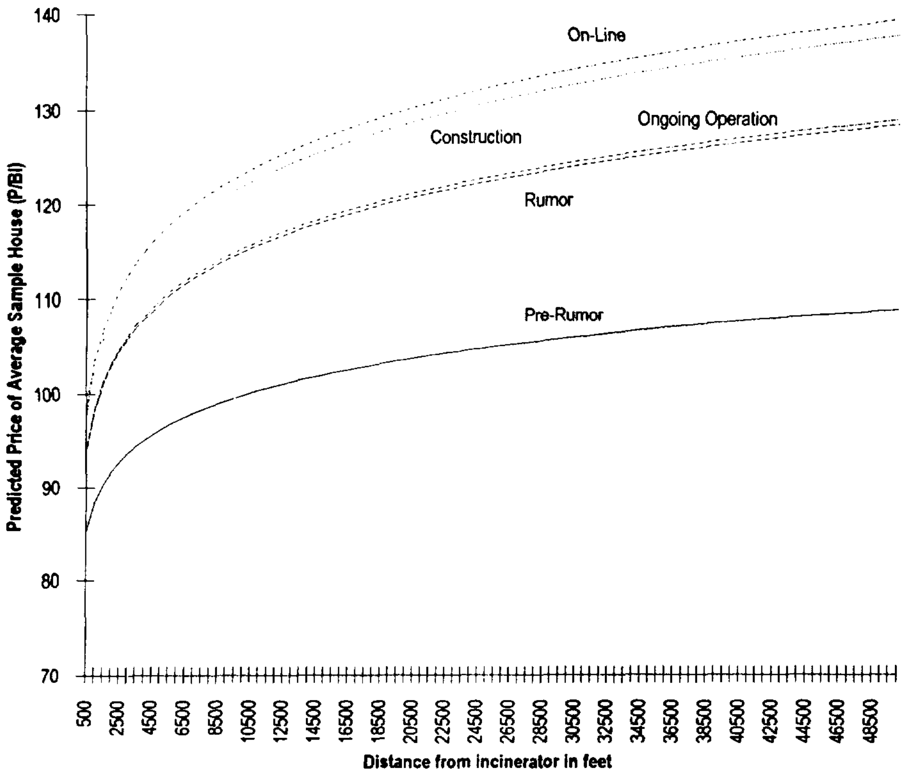

FIG. 2. Effect of distance on predicted house price from pooled regression with interactive variables.

pooled regression, in favor of the individual phase regressions.[9] Tastes evolve over time and holding the contribution of the various characteristics constant may be inappropriate.

V. CONCLUSIONS

The results of this study suggest that the adjustment of house prices to the construction and operation of an undesirable facility is much more complex and prolonged than previously indicated. The pooled model indicates some price response to rumors of a facility, and the evidence that prices respond at ground-breaking, before operation, is strongly supported by both models. The distance premium persists 7 years after the facility began operating. These results are consistent with Galster's hypothesis that those who most strongly view the plant as a negative externality will relocate as quickly as possible, potentially even before the facility is permitted and constructed. Additional residents will move once the plant is a certainty, and others will withhold their decision until the plant is in operation and they can weigh its actual effects.

[9] The calculated F statistic (40,2538) = 2.32, which rejects the null hypothesis (critical value at 5% = 1.59) of fixed coefficients.

The effect of the incinerator on the housing market not only changes over time but is not uniform across the town. A shift in demand from nearby to more distant houses results in prices rising for outlying houses, even though the evidence suggests that the incinerator is a negative externality for North Andover overall.

An interesting and timely application of our findings concerns citizen demands for compensation for the concentrated costs they bear as local hosts of a facility. Tompkins County, in upstate New York, has recently adopted an insurance program for neighbors of a newly sited and constructed landfill [16]. The program is intended to insure individuals against any loss of business income, decline in property values, or other damages due to environmental pollution resulting from the landfill. One provision of the policy is that new residents who purchase property after the landfill was sited are not eligible for compensation. This provision implicitly assumes that all the undesirable affects of the landfill are felt instantaneously upon a final siting and that the housing market and property values immediately and completely react, contrary to our evidence. While an insurance program of this nature tries to compensate local residents for the uneven burden they bear, its very design may omit or undercompensate many of the individuals it is designed to protect. The effect of the facility on housing values varies over the phases of the facility. Although this paper does not propose a compensation package, the results do indicate that the insurance programs and other measures of compensation could be better designed to reflect these changes.

The implications of this study should reach beyond the effects of siting resource recovery facilities or hazardous waste sites, which are among the most commonly studied undesirable facilities. Any locally unwanted land use, from a halfway house to a nuclear power plant, has the potential to affect local real estate values, although the profile of those effects through time may differ with the type of facility. This study will enable planners, officials, and residents to better understand the movement of prices over the life of an undesirable facility project and will help establish a method for estimating price profiles for many types of facilities. More accurate compensation packages could then be designed. It will also better illuminate the uneven burden local communities bear when hosting undesirable regional facilities.

REFERENCES

1. Richard V. Butler, The specification of hedonic indexes for urban housing, *Land Econom.* **58**(1), 96–108 (1982).
2. George C. Galster, Nuclear power plants and residential property values: A commentary on short-run versus long-run considerations, *J. Regional Sci.* **26**(4), 803–808 (1986).
3. Hays B. Gamble, and Roger H. Downing, Effects of nuclear power plants on residential property values, *J. Regional Sci.* **22**(4), 457–478 (1982).
4. Ole Hjelmar *et al*, Assessment of the environmental impact of MSWI ash disposal in Bermuda, "Environmental Impact Assessment for the Government of Bermuda," Water Quality Institute and the Bermuda Biological Station for Research, Inc. (1991).
5. Cheng Hsiao, "Analysis of Panel Data," Cambridge Univ. Press. (1990).
6. Janet E. Kohlhase, The impact of toxic waste sites on housing values, *J. Urban Econom.* **30**(1), 1–26 (1991).
7. Robert Mendelsohn, Daniel Hellerstein, Michael Huguenin, Robert Unsworth, and Richard Brazee, Measuring hazardous waste damages with panel models, *J. Environ. Econom. Management* **22**(3), 259–271 (1992).
8. Gregory Michaels and V. Kerry Smith, Market segmentation and valuing amenities with hedonic models: The case of hazardous waste sites, *J. Urban Econom.* **28**, 223–242 (1990).

9. Romayne Naylor, Mining proposal stirs fear: Firm calls it safe plan. *Keystone Gazette* August 29, 1 and 9 (1991).
10. *North Andover Citizen*, various issues (1974–1991).
11. Robin Phillips, Residential capitalization rates: Explaining intermetropolitan variation, 1974–1979. *J. Urban Econom* **23**, 278–290 (1988).
12. Kent E. Portney, Allaying the NIMBY syndrome: The potential for compensation in hazardous waste treatment facility siting, *Hazardous Waste* **1**(3), 411–421 (1984).
13. Jerome Rothenberg, George Galster, Richard Butler, and John Pitkin, "The Maze of Urban Housing Markets: Theory, Evidence and Policy," University of Chicago, Chicago, IL (1991).
14. Paul Slovic, Perception of risk, *Science* **236**, 280–285 (1987).
15. Richard D. Twark, Raymond W. Eyerly, and Roger H. Downing, The effect of nuclear power plants on residential property values: A new look at Three Mile Island, The Pennsylvania State University, Working Paper 90–10.
16. Elizabeth Voisin, Protect our property: Landfill opponents, *City and State*, March 13, p. 19 (1989).