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Does Hazardous Waste Matter?
Evidence from the Housing Market and the Superfund Program*

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Abstract

Under the Superfund program, the EPA initiates remedial clean-ups of hazardous waste sites where the release of hazardous substances poses imminent and substantial risks to public health and/or the environment. This paper estimates the capitalization into housing prices of the announcement that a site will be cleaned-up as part of the Superfund program. We utilize a variety of identification strategies ranging from linear adjustment to a regression discontinuity design based on knowledge of the rule that determines eligibility for a Superfund clean-up.

The estimates suggest that the presence of a Superfund site in a census tract is associated with an approximately 6% increase in median house prices in that tract and the immediately neighboring tracts roughly 20 years after sites became eligible for a Superfund clean-up. This finding implies that a site's placement on the Superfund eligible list is associated with an approximately $42 million (2000 $s) increase in property values 20 years later. This is roughly equivalent to our best estimate of the mean costs of a Superfund clean-up. We also find evidence of sorting in response to the clean-ups so that 20 years later the tracts with these sites within their borders have increased populations and a decline in the fraction of households on public assistance

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Introduction

In 1980 Congress passed and President Carter signed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which became known as the Superfund program. This landmark legislation gives the EPA the right to initiate remedial clean-ups at sites where a release or significant threat of a release of a hazardous substance that poses an imminent and substantial danger to public health or welfare and the environment. These clean-ups take many years and typically cost tens of millions of dollars. Since the passage of the Superfund legislation, more than 1,500 sites have been placed on the National Priorities List (NPL), which qualifies a site for the expenditure of federal remediation funds. As of 2000, clean-ups have been completed at roughly half of these sites at a cost of approximately $30 billion (2000$). Despite these expenditures, there has not been a systematic accounting of the benefits of Superfund clean-ups. This paucity of information on its benefits has made Superfund a very controversial program.[1]

This study empirically estimates the benefits of placement on the NPL and subsequent clean-up on residential property values and rental rates in the areas surrounding the site. The appeal of housing prices and rental rates as outcomes is that if housing markets are operating correctly, they will capture the health <u>and</u> aesthetic benefits of clean-ups. Thus, in principle, it is possible to measure the full welfare effects. The empirical challenge is that NPL sites, by their very assignment to the NPL, are the most polluted sites in the US. Thus, the evolution of housing prices in these areas may not be comparable to the evolution in the vast majority of the rest of the US.

This paper uses three primary identification strategies to estimate the capitalization of placement of a hazardous waste site on the NPL into census-tract level housing values and rental rates. First, we use linear adjustment to control for heterogeneity across census tracts with and without Superfund sites. We implement this analysis on the 1,000 Superfund sites with available housing price data and on the subset of sites that were on the first NPL published in 1983.

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[1] In March 1995 in Congressional testimony, Katherine Probst of Resources for the Future said, "Although the program has been in existence for over 14 years, we still know very little about the benefits of site cleanup or about the associated costs." At the same hearing, John Shanahan of the Heritage Foundation said, "Superfund…is widely regarded as a wasteful and ineffective program in dire need of substantive reform."

Our second and third identification strategies exploit the procedure used to develop the first NPL. After the Superfund legislation was enacted in 1980, 14,697 sites were referred to the EPA and investigated as potential candidates for remedial action. Through the assessment process, the EPA winnowed this list down to the 690 sites where the health and environmental risks were deemed to be the highest. Since the federal government had only allocated enough money to clean-up 400 sites, it was necessary to further cut this list down. To choose the 400 sites eligible for clean-up, the EPA developed the Hazardous Ranking System (HRS) which assigns each site a score ranging from 0 to 100. The HRS aimed to provide a measure of relative risk but according to the EPA did not reflect absolute levels of risk in the early 1980s. 400 sites had scores greater than 28.5, so the EPA required a score of at least 28.5 for a site to be eligible for placement on the NPL and, in turn, Superfund remediation activities.

The second approach compares the evolution of property values in census tracts with hazardous waste sites with initial HRS scores above and below the 28.5 cut-off among these 690 sites. The assumption is that the sites below 28.5 form a valid counterfactual for the evolution of housing prices at sites above the threshold. It is also possible to focus the comparisons in the "neighborhood" of the cut-off and the third approach does just this by implementing a quasi-experimental regression discontinuity design (Cook and Campbell 1979).

The analysis is conducted with the most comprehensive data file ever compiled on Superfund sites and housing prices and rental rates. The data include information on housing prices and their determinants at the census tract level from the 1980, 1990, and 2000 censuses. We also collected detailed histories on the more than 1,400 hazardous waste sites placed on the NPL by the beginning of 2000 and the 287 sites that narrowly missed placement on the initial NPL in 1983. We obtained the HRS score and the census tract that they are located in for all of these sites. For the sites that made it onto the NPL, we determined the EPA's expected costs of clean-up, the actual costs of clean-up, the size (in acres) of the hazardous waste site, the date of placement on the NPL, the date that a clean-up plan was announced, the date that clean-up was initiated, and for those sites where the clean-up was completed the dates of completion, as well as deletion from the NPL.

Our approach has a number of important advantages over previous research on the benefits of the Superfund program. It is a significant departure from the typical Superfund study that examines a single site or a handful of sites (Smith and Michael 1990; Kohlhase 1991; Kiel 1995; Gayer Hamilton, and Viscusi 2000 and 2002). The comprehensiveness of this data file means that the results are informative about the program's average impact across all sites, rather than being specific to a handful of sites.

A further advantage of this study is that we present estimates from a variety of identification strategies. As a result, it is possible to assess the robustness of the results to alternative identification assumptions. Additionally, we assume that individuals transmit their valuations of the reduction in health risks and aesthetic improvements of future clean-ups through the housing market. Consequently, we are not forced to rely on the notoriously poor estimates of risk to human health associated with the thousands of chemicals present at these sites. The point is that any welfare calculations are derived from consumers' revealed preferences and not from EPA laboratories and assumptions about the appropriate value of a statistical life.[2] Finally, we collected the dates that sites reach various milestones in the clean-up process and test whether the effect on housing prices and rental rates differs at these stages.

Across the different identification strategies, the estimates suggest that the presence of a Superfund site in a census tract is associated with an approximately 6% increase in median house prices in that tract and the immediately neighboring tracts roughly 20 years after sites became eligible for a Superfund clean-up. This finding implies that a site's placement on the Superfund eligible list is associated with an approximately $42 million (2000 $s) increase in property values 20 years later. This is roughly equivalent to our best estimate of the mean costs of a Superfund clean-up. We also find evidence of sorting in response to the clean-ups so that 20 years later the tracts with these sites within their borders have increased populations and a decline in the fraction of households on public assistance

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[2] Viscusi and Hamilton (1999) use EPA provided estimates of the probability of cancer cases at a subsample of sites and find that at the median site expenditure the average cost per cancer case averted by the clean-up exceeds $6 billion. They also find evidence that the decision about which NPL sites to clean-up are associated with local measures of political activism. Other researchers have found less decisive evidence on the relationship between local community's characteristics and EPA decisions on which sites to clean-up (Hird 1993, 1994; Zimmerman 1993; Gupta et al., 1995 and 1996).

The paper proceeds as follows. Section I describes the conceptual framework. Section II provides background on the Superfund program and how its initial implementation may provide the conditions necessary to credibly estimate the benefits of Superfund clean-ups. Section III details the data sources and provides some summary statistics. Sections IV and V review the econometric methods and report on the empirical findings. Section VI interprets the findings and concludes the paper.

I. Conceptual Framework and Research Design

This paper's primary goals are to obtain reliable estimates of the benefits of Superfund clean-ups and, more broadly, measures of individuals' valuations of clean local environments. The difficulty is that an explicit market for proximity to hazardous waste sites does not exist. This section explains why we believe that estimating and valuing the health benefits is currently unlikely to be a reliable method to answer these questions. It then explains why data on the housing market may offer an opportunity to achieve our goals. Specifically, it briefly reviews hedonic theory, which spells out the assumptions necessary to interpret changes in housing prices as welfare changes. It also explains the econometric identification problems that plague the implementation of the hedonic method.

A. Difficulties with the Health Effects Approach to Valuing Clean-Ups

The "health effects" approach is based on the determination of the reduction in rates of morbidity and mortality associated with proximity to a hazardous waste site due to a clean-up. These reductions are then multiplied by estimates of willingness to pay to avoid morbidities and fatalities.

The difficulties with the health effects approach are best understood by consideration of the four steps involved in these calculations. The first step is the determination of each of the chemicals present at a site and the pathway(s) (e.g., air, water, or soil) by which humans come into contact with them. Through tests conducted at the site, the EPA obtains pathway-specific estimates of the concentrations of each chemical before the clean-up. They also specify goals for these concentrations once the clean-up is completed. The result is expected chemical by pathway specific reductions in concentrations.

The second step is the estimation of the health benefits of these pollution reductions, which requires the development of pathway-specific estimates of the health risk from each chemical. The difficulty here is that more than 65,000 industrial chemicals have been in commercial production since WWII in the U.S., and the human health effects of many of them are unknown. This problem is further complicated by heterogeneity in the health effects across the pathway of exposure.[3]

Third, even for those sites where reliable health data exist, a calculation of the health benefit requires assumptions about the size of the affected population and the length of exposure through each potential pathway. This task is complicated by the fact that people tend to avoid contact with known risks and thus proximity to a hazardous waste site may not be informative about exposure. Hamilton and Viscusi (1999) underscore the difficulty in developing reliable exposure assumptions and that the EPA often uses ones that seem unrealistic.

Fourth, the changes in morbidity and mortality must be monetized by using estimates of individuals' willingness to pay (WTP) to avoid these events. There is an extensive literature on the value of a statistical life (see e.g., Viscusi 1993 and Ashenfelter and Greenstone 2004a and 2004b), but estimates of trade-offs between wealth and morbidity are less pervasive. Moreover, the application of available estimates always relies on an assumption that the literature's estimates of WTP are relevant for the affected subpopulation.

In sum, the health effects approach has many steps and each of them is uncertain. In light of these scientific, empirical, and data quality concerns, we feel that the health effects approach is unlikely to produce credible estimates of the benefits of Superfund clean-ups. Further by its very nature, this approach cannot account for the potential aesthetic benefits of these clean-ups.

B. The Hedonic Method and Its Econometric Difficulties

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[3] For example, endrin has negative health consequences if it is swallowed but inhalation or contact with the skin is believed to be safe. Similarly, arsenic is dangerous if you swallow it or inhale in (through dust), but skin contact from dirt or water is relatively harmless.

As an alternative to the health effects approach, we use the housing market to infer individuals' valuations of clean-ups. Economists have estimated the association between housing prices and environmental amenities at least since Ridker (1967) and Ridker and Henning (1967). However, Rosen (1974) was the first to give this correlation an economic interpretation. In the Rosen formulation, a differentiated good can be described by a vector of its characteristics, $Q = (q_1, q_2, \ldots, qn)$. In the case of a house, these characteristics may include structural attributes (e.g., number of bedrooms), the provision of neighborhood public services (e.g., local school quality), and local environmental amenities (e.g., proximity to a hazardous waste site). Thus, the price of the i^{th} house can be written as:

(2) $P_i = P(q_1, q_2, \ldots, q_n)$.

The partial derivative of P(•) with respect to the n^{th} characteristic, $\partial P/\partial q_n$, is referred to as the marginal implicit price. It is the marginal price of the n^{th} characteristic implicit in the overall price of the house.

In a competitive market, the locus between housing prices and characteristic, or the hedonic price schedule (HPS), is determined by the equilibrium interactions of consumers and producers.[4] The HPS is the locus of tangencies between consumers' bid functions and suppliers' offer functions. The gradient of the implicit price function with respect to proximity to a hazardous waste site gives the equilibrium differential that allocates individuals across locations so that individuals living in close proximity to a hazardous waste site are compensated for this disamenity. Locations close to hazardous waste sites must have lower housing prices to attract potential homeowners. Importantly, in principle, the price differential reflects both individuals valuations of the health risk associated with proximity to a site and the site's damage to a neighborhood's aesthetics. In this respect, the hedonic approach provides a fuller examination of the valuation than an exclusive focus on the health risks.[5]

At each point on the HPS, the marginal price of a housing characteristic is equal to an individual's marginal willingness to pay (MWTP) for that characteristic and an individual supplier's marginal cost of producing it. Since the HPS reveals the MWTP at a given point, it can be used to infer

[4] See Rosen (1974), Freeman (1993), and Palmquist (1991) for details.
[5] The hedonic approach cannot account for aesthetic benefits that accrue to nonresidents that, for example, engage in recreational activities near the site. The health effects approach has this same limitation.

the welfare effects of a marginal change in a characteristic. The overall slope of the HPS provides a measure of the average MWTP across all consumers.

Consistent estimation of the HPS in equation (1) is extremely difficult since there may be unobserved factors that covary with both environmental amenities and housing prices.[6] For example, areas with hazardous waste sites tend to have lower population densities, a higher proportion of detached single unit houses, and are more likely to be located in the Northeast. Consequently, cross-sectional estimates of the association between housing prices and proximity to a hazardous waste site may be severely biased due to omitted variables. In fact, the cross-sectional estimation of the HPS has exhibited signs of misspecification in a number of settings, including the relationships between land prices and school quality, total suspended particulates air pollution, and climate variables (Black 1999; Chay and Greenstone 2004; Deschenes and Greenstone 2004).[7]

The consequences of the misspecification of equation (2) were recognized almost immediately after the original Rosen paper. For example, Small (1975) wrote:

> I have entirely avoided…the important question of whether the empirical difficulties, especially correlation between pollution and unmeasured neighborhood characteristics, are so overwhelming as to render the entire method useless. I hope that…future work can proceed to solving these practical problems….The degree of attention devoted to this [problem]…is what will really determine whether the method stands or falls…" [p. 107].

In the intervening years, this problem of misspecification has received little attention from empirical researchers, even though Rosen himself recognized it.[8] One of this paper's aims is to demonstrate that it may be possible to obtain credible hedonic estimates with a quasi-experimental approach.

In principle, the hedonic method can also be used to recover the entire demand or MWTP function.[9] This would be of tremendous practical importance, because it would allow for the estimation

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[6] See Halvorsen and Pollakowski (1981) and Cropper et al. (1988) for discussions of misspecification of the HPS due to incorrect choice of functional form for observed covariates.

[7] Similar problems arise when estimating compensating wage differentials for job characteristics, such as the risk of injury or death. The regression-adjusted association between wages and many job amenities is weak and often has a counterintuitive sign (Smith 1979; Black and Kneisner 2003).

[8] Rosen (1986) wrote, "It is clear that nothing can be learned about the structure of preferences in a single cross-section…" (p. 658), and "On the empirical side of these questions, the greatest potential for further progress rests in developing more suitable sources of data on the nature of selection and matching…" (p. 688).

[9] Epple and Sieg (1999) develop an alternative approach to value local public goods. Sieg, Smith, Banzhaf, and Walsh (2000) apply this locational equilibrium approach to value air quality changes in Southern California from 1990-1995.

of the welfare effects of nonmarginal changes. Rosen (1974) proposed a 2-step approach for estimating the MWTP function, as well as the supply curve. In recent work, Ekeland, Heckman and Nesheim (2004) outline the assumptions necessary to identify the demand (and supply) functions in an additive version of the hedonic model with data from a single market.[10] In this paper, we focus on the consistent estimation of equation (2), which is the foundation for welfare calculations of both marginal and non-marginal changes.

II. The Superfund Program and a New Research Design

A. History and Broad Program Goals

Before the regulation of the disposal of hazardous wastes by the Toxic Substances Control and Resource Conservation and Recovery Acts of 1976, industrial firms frequently disposed of wastes by burying them in the ground. Love Canal, NY is perhaps the most infamous example of these disposal practices. Throughout the 1940s and 1950s, this area was a landfill for industrial waste and more than 21,000 tons of chemical wastes were ultimately deposited there. The landfill closed in the early 1950s and over the next two decades a community developed in that area. In the 1970s, Love Canal residents began to complain of health problems, including high rates of cancer, birth defects, miscarriages, and skin ailments. Eventually, New York State found high concentrations of dangerous chemicals in the air and soil.[11] Ultimately, concerns about the safety of this area prompted President Carter to declare a State of Emergency that led to the permanent relocation of the 900 residents of this area.

The Love Canal incident helped to galvanize support for addressing the legacy of industrial waste and these political pressures led to the creation of the Superfund program in 1980. Under this program, the EPA may respond to an actual or potential release of a hazardous substance by either an immediate removal or a full clean-up that permanently removes the danger and returns the site to its "natural state."

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[10] Heckman, Matzkin, and Nesheim (2002 and 2003) examine identification and estimation of nonadditive hedonic models and the performance of estimation techniques for additive and nonadditive models.
[11] The EPA claims that 56% of the children born in Love Canal between 1974 and 1978 had birth defects (EPA 2000).

The immediate removal clean-ups are responses to environmental emergencies and are generally short-term actions aimed at diminishing an immediate threat. Examples of such actions include cleaning up waste spilled from containers and the construction of fences around dangerous sites.[12] These short-term, emergency clean-ups are not intended to remediate the underlying environmental problems and only account for a small proportion of Superfund activities. These actions are not discussed further in this paper.

The centerpiece of the Superfund program, and the focus of this paper, is the long-run remediation of hazardous waste sites. These remediation efforts aim to reduce permanently the dangers due to hazardous substances that are serious, but not considered imminently life-threatening. Once initiated, these clean-ups can take many years to complete. As of 2000, roughly 1,500 sites had been placed on the NPL and thereby chosen for these long-run clean-ups. The next subsection describes the selection process, which forms the basis of our research design.

B. Site Assessment Process

The identification of Superfund hazardous waste sites is a multi-step process. The first step is the referral to the EPA of potential hazardous waste sites by other branches of federal or local government. Through 1996, 40,665 sites have been referred to the EPA for possible inclusion on the NPL. The second step consists of tests for whether any of the hazardous chemicals at the site exceed the minimum 'reportable release' levels for the relevant chemical specified in the Code of Federal Regulations Part 302.4. Sites that exceed any of the minimum levels move along to the third step where a "preliminary assessment" of the prevailing risk is conducted. This assessment includes the mapping of the site, identification of release points, visual estimates of the types and quantities of contaminants, and possibly some sampling. The fourth step is reserved for sites where the preliminary assessment suggests that the

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[12] A well known example of an immediate removal clean-up occurred at the "Valley of the Drums" in Bullitt County, Kentucky in 1981. At this former waste disposal site, the EPA discovered elevated levels of heavy metals, volatile organic compounds, and plastics in ground water, surface water and soils. Upon investigation, it became evident that 17,000 deteriorating and leaking waste drums were the source of the pollution problem. The EPA removed the drums to solve the short-term problem, but the site was eventually placed on the NPL and received a full clean-up.

site might be of a great enough risk that listing on the NPL is a legitimate possibility. This "site inspection" phase involves the collection of further samples and further analysis of risk.[13]

The final step of the assessment process is the application of the Hazardous Ranking System (HRS) and this test is reserved for the sites that fail to be rejected as possible Superfund candidates by the first four steps. The EPA developed the HRS in 1982 as a standardized approach to quantify and compare the human health and environmental risk among sites, so that those with the most risk could be identified. The original HRS evaluated the risk for the exposure to chemical pollutants along three migration 'pathways': groundwater, surface water, and air.[14] The toxicity and concentration of chemicals, the likelihood of exposure and proximity to humans, and the population that could be affected are the major determinants of risk along each pathway. The non-human impact that chemicals may have is considered during the process of evaluating the site, but plays a minor role in determining the HRS score. The Data Appendix provides further details on the determination of HRS test scores.

The HRS produces a score for each site that ranges from 0 to 100. From 1982-1995, any hazardous waste site that scored 28.5 or greater on a HRS test was placed on the NPL, making them eligible for a Superfund clean-up.[15] [16] Sites that are not placed on the NPL are ineligible for a federally financed remedial clean-up.

C. Clean-Up of NPL Sites

Once a site is placed on the NPL, it can take many years until it is returned to its natural state. The first step toward clean-up for NPL sites is a further study of the extent of the environmental problem

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[13] If there is an existing hazard that can be readily contained, or if there is a clear and immediate health risk, emergency action can be taken at any step in the assessment process. .

[14] In 1990, the EPA revised the HRS test so that it also considers soil as an additional pathway.

[15] In 1980 every state received the right to place one site on the NPL without the site having to score at or above 28.5 on the HRS test. As of 2003, 38 states have used their exception. It is unknown whether these sites would have received a HRS score above 28.5.

[16] In 1995 the criteria for placement on the NPL were altered so that a site must have a HRS score greater than 28.5 and the governor of the state in which the site is located must approve the placement. There are currently a number of potential NPL sites with HRS scores greater than 28.5 that have not been proposed for NPL placement due to known state political opposition. We do not know the precise number of these sites because our Freedom of Information Act request for information about these sites was denied by the EPA.

and how best to remedy it. This leads to the publication of a Record of Decision (ROD), which outlines the clean-up actions that are planned for the site. This process of selecting the proper remediation activities is often quite lengthy. In our primary sample, the median time between NPL listing and the release of the ROD is roughly 4 years. Even after the ROD is released, it can take a few years for remediation activities to be initiated. For example, the median time between NPL placement and initiation of clean-up is between 6 and 7 years.

The site receives the "construction complete" designation once the physical construction of all clean-up remedies is complete, the immediate threats to health have been removed, and the long-run threats are "under control". In our primary sample, the median number of year between NPL placement and the application of the "construction complete" designation is 12 years. It usually takes about one more year for the EPA to officially delete the site from the NPL. A number of factors are thought to explain the long time for clean-up, but the involvement of local communities in the decision making and resource constraints are two that are mentioned frequently.

D. 1982 HRS Scores as the Basis of a New Research Design

Reliable estimates of the benefits of the Superfund program and, more generally, local residents' willingness to pay for the clean-up of hazardous waste sites would be of tremendous practical importance. The empirical difficulty is that clean-ups are not randomly assigned to sites and they may be correlated with unobserved determinants of housing prices. In this case, empirical estimates of the benefits of clean-ups will be confounded by the unobserved variables. Consequently, it is necessary to develop a valid counterfactual for the evolution of property values at Superfund sites in the absence of the site's placement on the NPL and eventual clean-up. This may be especially difficult, because the NPL sites are the most polluted in the U.S., so the evolution of housing prices near these sites may not be comparable to the remainder of the US, even conditional on observable covariates.

The process of the initial assignment of sites to the NPL may provide a credible opportunity to obtain unbiased estimates of the effect of clean-ups on property values. The initial Superfund legislation directed the EPA to develop a NPL of "at least" 400 sites (Section 105(8)(B) of CERCLA). After the legislation's passage in 1980, 14,697 sites were referred to the EPA and investigated as potential candidates for remedial action. Through the assessment process, the EPA winnowed this list to the 690 most dangerous sites. To comply with the requirement to initiate the program, the EPA was given little more than a year to develop the HRS test. Budgetary considerations led the EPA to set a qualifying score of 28.5 for placement on the NPL so that the legislative requirement of "at least" 400 sites was met.[17] This process culminated with the publication of the initial NPL on September 8, 1983.

The central role of the HRS score has not been noted previously by researchers and provides a compelling basis for a research design that compares outcomes at sites with initial scores above and below the 28.5 cut-off for at least three reasons. First, the 28.5 cut-off was established after the testing of the 690 sites was complete. Thus, it is very unlikely that the scores were manipulated to affect a site's placement on the NPL. Further, this means that the initial HRS scores were not based on the expected costs or benefits of clean-up (except through their indirect effect on the HRS score) and solely reflected the EPA's assessment of the human health and environmental risks associated with the site.

Second, the EPA and scientific community were uncertain about the health consequences of many of the tens of thousands of chemicals present at these sites.[18] Consequently, the individual pathway scores and, in turn the HRS score, were noisy measures of the true risks. Further, the threshold was not selected based on evidence that HRS scores below 28.5 sites posed little risk to health. In fact, the Federal Register specifically reported that, "EPA has not made a determination that sites scoring less than 28.50 do not present a significant risk to human health, welfare, or the environment" (Federal Register 1984, pp. TK). Further, the EPA openly acknowledged that this early version of the HRS was

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[17] Exactly 400 of the sites on the initial NPL had HRS scores exceeding 28.5. The original Superfund legislation gave each state the right to place one site on the NPL without going through the usual evaluation process. Six of these "state priority sites" were included on the original NPL released in 1983. Thus, the original list contained the 400 sites with HRS scores exceeding 28.5 and the 6 state exceptions. See the Data Appendix for further details.

[18] A recent summary of Superfund's history makes this point. "At the inception of EPA's Superfund program, there was much to be learned about industrial wastes and their potential for causing public health problems. Before this problem could be addressed on the program level, the types of wastes most often found at sites needed to be determined, and their health effects studied. Identifying and quantifying risks to health and the environment for the extremely broad range of conditions, chemicals, and threats at uncontrolled hazardous wastes sites posed formidable problems. Many of these problems stemmed from the lack of information concerning the toxicities of the over 65,000 different industrial chemicals listed as having been in commercial production since 1945" (EPA 2000, p. 3-2).

uninformative about absolute risks and that the development of such a test would require “greater time and funds” (EPA 1982).[19] Despite its failure to measure absolute risk, the EPA claimed that the HRS was useful as a means to determine relative risk. Overall, the noisiness in the score and arbitrariness of the 28.5 cutoff are an attractive feature of this research design.

Third, the selection rule that determined the placement on the NPL is a highly nonlinear function of the HRS score. This naturally lends itself to a comparison of outcomes at sites “near” the 28.5 cut-off. If the unobservables are similar around the regulatory threshold, then a comparison of these sites will control for all omitted factors correlated with the outcomes. This test has the features of a quasi-experimental regression-discontinuity design (Cook and Campbell 1979).

Before proceeding, it is worth highlighting two other points about our approach. First, an initial score above 28.5 is highly correlated with eventual NPL status but is not a perfect predictor of it. This is because some sites were rescored and the later scores determined whether they ended up on the NPL.[20] The subsequent analysis uses an indicator variable for whether a site’s initial (i.e., 1982) HRS score was above 28.5 as an instrumental variable for whether a site was on the NPL in 1990 (and then again in 2000). We use this approach rather than a simple comparison of NPL and non-NPL sites, because it purges the variation in NPL status that is due to political influence, which may reflect the expected benefits of the clean-up.

Second, the research design of comparing sites with HRS scores “near” the 28.5 is unlikely to be valid for any site that received an initial HRS score after 1982. This is because once the 28.5 cut-off was set, the HRS testers were encouraged to minimize testing costs and simply determine whether a site exceeded the threshold. Consequently, testers generally stop scoring pathways once enough pathways are

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[19] One way to measure the crude nature of the initial HRS test is by the detail of the guidelines used for determining the HRS score. The guidelines used to develop the initial HRS sites were collected in a 30 page manual. Today, the analogous manual is more than 500 pages.

[20] As an example, 144 sites with initial scores above 28.5 were rescored and this led to 7 sites receiving revised scores below the cut-off. Further, complaints by citizens and others led to rescoring at a number of sites below the cut-off. Although there has been substantial research on the question of which sites on the NPL are cleaned-up first (see, e.g., Viscusi and Hamilton 1991 and Sigman 2001), we are unaware of any research on the determinants of a site being rescored.

scored to produce a score above the threshold. When only some of the pathways are scored, the full HRS score is unknown and the quasi-experimental regression discontinuity design is inappropriate.[21]

E .What Questions Can Be Answered?

Our primary outcome of interest is the median housing value in census tracts near hazardous waste site. In a well-functioning market, the value of a house equals the present discounted value of the stream of services it supplies into the infinite future. In light of the practical realities of the long period of time between a site's initial listing on the NPL and eventual clean-up and the decennial measures of housing prices, this subsection clarifies the differences between the theoretically correct parameters of interest and the estimable parameters.

Define R as the monetary value of the stream of services provided by a house over a period of time (e.g., a year), or the rental rate. We assume that R is a function of an index that measures individuals' perception of the desirability of living near a hazardous waste site. We denote this index as H and assume that it is a function of the expected health risks associated with living in this location <u>and</u> any aesthetic disamenities. It is natural to assume that $\partial R / \partial H < 0$.

Now, consider how H changes for residents of a site throughout the different stages of the Superfund process. Specifically,

(2) H_0 = Index Before Superfund Program Initiated

H_1 = Index After Site Placed on the NPL

H_2 = Index Once ROD Published/Clean-Up is Initiated

H_3 = Index Once "Construction Complete" or Deleted from NPL

It seems reasonable to presume that $H_0 > H_3$ so that $R(H_3) > R(H_0)$ because the clean-up reduces the health risks and increases the aesthetic value of proximity to the site. It is not evident whether H_1 and H_2 are greater than, less than, or equal to H_0. This depends on how H evolves during the clean-up process. It

[21] In 1990 the HRS test was revised so as to place an even greater emphasis on the risk to human health relative to other non-human environmental risks. The cutoff level of 28.5 was maintained, but studies have shown that scores using the two tests are often very different, with scores using the revised HRS generally being lower (Brody 1998).

is frequently argued that the announcement that a site is eligible for Superfund remediation causes H to increase, but, by its very nature, H is unobservable.[22]

We can now write the constant dollar price of a house (measured after NPL listing) that is in the vicinity of a hazardous waste site, with a HRS score exceeding 28.5:

$$(3)\ P^{HRS>28.5} = \sum_{t=0}^{\infty} \ 1(H_t = H_1)\, \delta^t R(H_1) + 1(H_t = H_2)\, \delta^t R(H_2) + 1(H_t = H_3)\, \delta^t R(H_3).$$

In this equation, the indicator variables 1(·) equal 1 when the enclosed statement is true in period t and δ is a discount factor based on the rate of time preferences. The equation demonstrates that upon placement on the NPL, $P^{HRS>28.5}$ reflects the expected evolution of H throughout the clean-up process.[23] The key implication of equation (3) is that $P^{HRS>28.5}$ varies with the stage of the Superfund clean-up at the time that it is observed. For example, it is higher if measured when $H_t = H_3$ than when $H_t = H_1$, because the years of relatively low rental rates have passed.

The constant dollar price of a house located near a hazardous waste site with a HRS score below 28.5 is:

$$(4)\ P^{HRS<28.5} = \sum_{t=0}^{\infty} \ \delta^t R(H_0).$$

We assume that H is unchanged for the sites that narrowly missed being placed on the NPL due to HRS scores below 28.5. If this assumption is valid, then $P_t^{HRS<28.5}$ is identical in all periods.

At least two policy-relevant questions are of interest. First, how much are local residents' willing to pay for the listing of a local hazardous waste site on the NPL? This is the ideal measure of the welfare consequences of a Superfund clean-up. In principle, it can be measured as:

$$(5)\ t_{\text{WTP for Superfund}} = [P^{HRS>28.5} \mid H_t = H_1] - P^{HRS<28.5}.$$

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[22] McCluskey and Rausser (2003) and Messer, Schulze, Hackett, Cameron, and McClelland (2004) provide evidence that prices immediately decline after the announcement that a local site has been placed on the NPL. The intuition is that residents knew that the site was undesirable but were unlikely to know that it was one of the very worst sites in the country.

[23] The stigma hypothesis states that even after remediation individuals will assume incorrectly that properties near Superfund sites still have an elevated health risk. Thus, there is a permanent negative effect on property values. See Harris (1999) for a review of the stigma literature.

It is theoretically correct to measure $P^{HRS>28.5}$ at the instant that the site is placed on the NPL to account for the Superfund program's full effect on the present discounted stream of housing services at that site. Notice, the sign of $t_{Superfund}$ is ambiguous and depends on the time until clean-up, the discount rate, and the change in H at each stage of the clean-up. In practice, our estimates of $t_{WTP\ for\ Superfund}$ are likely to be biased upwards relative to the ideal because we can only observe $[P^{HRS>28.5}|1990 \text{ or } 2000]$ when many of the low rental rate years where $H_t = H_1$ have passed.

Second, how does the market value the clean-up of a hazardous waste site? This is represented by:

(6) $t_{Clean\text{-}Up} = [P^{HRS>28.5} \mid H = H_3] - P^{HRS<28.5}$,

which is the difference in the value of the property after remediation is completed and the average value of sites that narrowly miss placement on the NPL. This is a measure of how much local governments should pay for a clean-up. Numerous sites from the initial NPL list were cleaned up by 2000, so it is feasible to estimate $[P^{HRS>28.5} \mid H = H_3]$ with data from that census year. It is important to note that $t_{Clean\text{-}Up}$ is not a welfare measure since by 2000 the composition of consumers is likely to have changed.

III. Data Sources and Summary Statistics

A. Data Sources

We test whether the placement of hazardous waste sites on the NPL affects local housing prices. To implement this, we use census tracts as the unit of analysis, which are the smallest geographic unit that can be matched across the 1980, 1990, and 2000 Censuses. They are drawn so that they include approximately 4,000 people.

The analysis is conducted with the Geolytics company's *Neighborhood Change Database*, which provides a panel data set of census tracts that is based on 2000 census tract boundaries.[24] The analysis is

[24] More information on how the 1980 and 1990 census tracts were adjusted to fit the 2000 census tract boundaries can be found at Geolytics' website, www.geolytics.com.

restricted to census tracts with non-missing 1980 mean and 1990 and 2000 median housing prices.[25] The database also contains most of the standard demographic and housing characteristic data available from the Censuses. These variables are aggregated to the census tract-level and used as controls in the subsequent analysis. Each of the NPL sites and hazardous waste sites with initial HRS scores below 28.5 are assigned to individual census tracts. The Data Appendix describes the process used to make these assignments.

A key feature of the analysis is the initial HRS scores for the 690 hazardous waste sites considered for placement on the first NPL on September 8, 1983. The HRS composite scores, as well as groundwater, surface water, and air pathway scores, for each site were obtained from the Federal Register (198?).

We collected a number of other variables for the NPL sites. Various issues of the Federal Register were used to determine the dates of NPL listing. The EPA provided us with a data file that reports the dates of release of the ROD, initiation of clean-up, completion of construction, and deletion from the NPL for sites that achieved these milestones. We also collected data on the expected costs of clean-up before remediation is initiated and actual costs for the sites that reached the construction complete stage. The RODs also provided information on the size (measured in acres) of the hazardous waste sits. The Data Appendix provides explanations of how these variables were collected and other details on our data sources.

B. Summary Statistics

The analysis is conducted with two data samples. We refer to the first as the "All NPL Sample." The focus in this sample is the census tracts with the 1,436 hazardous waste sites placed on the NPL by January 1, 2000 within their boundaries. The second is labeled the "1982 HRS Sample" and it is

[25] There are 65,443 census tracts based on 2000 boundaries. Of these, 16,887 census tracts have missing 1980 mean housing values, and an additional 238 and 178 have missing 1990 and 2000 median housing values, respectively. Also, note that the median house prices are unavailable in 1980 but median rental rates are available in all years.

comprised of the census tracts with hazardous waste sites tested for inclusion on the initial NPL within their boundaries, regardless of their eventual placement on the NPL.

Table 1 presents some summary statistics on the hazardous waste sites in these two samples. The entries in column (1) are from the All NPL Sample with the sample restrictions that we were able to place the NPL site in a census tract and that there is non-missing housing price data in 1980, 1990, and 2000 for that tract. After these sample restrictions, our sample includes 984 sites or nearly 70% of the 1,436 sites ever placed on the NPL by 2000. Columns (2) and (3) report data from the 1982 HRS Sample. The column (2) entries are based on the 490 sites that we were able to place in a census tract with non-missing housing price data in 1980, 1990, and 2000. Column (3) reports on the remaining 184 sites with certain census tract placement but incomplete housing price data.

Panel A reports on the timing of the placement of sites on the NPL. Column (1) reveals that about 85% of all NPL sites received this designation in the 1980s. Together, columns (2) and (3) demonstrate that 441 of the 674 sites in the 1982 HRS sample (with certain census tract placement) eventually were placed on the NPL. This exceeds the 400 sites that Congress set as an explicit goal, because, as we have discussed, some sites with initial scores below 28.5 were rescored and eventually received scores above the threshold. Most of this rescoring occurred in the 1986-1990 period. Panel B provides mean HRS scores, conditioned on scores above and below 28.5. Interestingly, the means are similar across the columns

Panel C reports on the size of the hazardous waste sites measured in acres. Note, this variable is only available for NPL sites since it is derived from the RODs. In the three columns, the median site size ranges between 25 and 35 acres. The mean is substantially larger, which is driven by a few sites. The small size of most sites suggests that any expected effects on property values may be confined to relatively small geographic areas.[26] In the subsequent analysis, we will separately test for effects in the census tracts that contain the sites and tracts that neighbor these tracts.

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[26] In a few instances, the pollutants at Superfund sites contaminated waterways that supply local residents' drinking water. In these cases, it may reasonable to presume that the effect on property values will be more widespread.

Panel D provides evidence on the amount of time required for the completion of clean-ups. The median time until different clean-up milestones are achieved is reported, rather than the mean, because many sites have not reached all of the milestones yet. As an example, only 16 of the NPL sites in column (2) received the construction complete designation by 1990. Thus, when we measure the effect of NPL status on 1990 housing prices, this effect will almost entirely be driven by sites where remediation activities are unfinished. By 2000, the number of sites in the construction complete or deleted category had increased dramatically to 198. In column (1), the number of sites that were construction complete by 1990 and 2000 are 26 and 479, respectively.

Panel E reports the expected costs of clean-up for NPL sites. This information was obtained from the sites' RODs and provides a measure of the expected costs (in 2000 $) of the clean-up before any remedial activities have begun. These costs include all costs expected to be incurred during the active clean-up phase, as well the expected costs during the operation and maintenance phase that is subsequent to the assignment of the construction complete designation.

In the All NPL Sample, the estimated cost data is available for 756 of the 984 NPL sites. The mean and median expected costs of clean-up are $27.8 million and $10.3 million (2000 $'s). The larger mean reflects the high cost of a few clean-ups—for example, the 95th percentile expected cost is $86.3. In the 1982 HRS Sample in column (2), the analogous figures are $27.6 million and $14.8 million. Conditional on construction complete status, the mean cost is $20.6 million.

The final panel reports estimated and actual costs for the subsample of construction complete sites where both cost measures are available. To the best of our knowledge, the estimated and actual cost data have never been brought together for the same set of sites. The conventional wisdom is that the actual costs greatly exceed the estimated costs of clean-up and this provides the first opportunity to test this view. The data appear to support the conventional wisdom as the mean actual costs are 40%-60% higher than the mean expected costs across the three columns. The findings are similar for median costs.

A comparison of columns (2) and (3) across the panels reveals that the sites with and without complete housing price data are similar on a number of dimensions. For example, the mean HRS score conditional on scoring above and below 28.5 is remarkably similar. Further, the size and cost variables are comparable in the two columns. Consequently, it seems reasonable to conclude that the sites without complete housing price data are similar to the column (2) sites, suggesting the subsequent results may be representative for the entire 1982 HRS Sample.

We now graphically summarize some other features of our two samples. Figure 1 displays the geographic distribution of the 984 hazardous waste sites in the All NPL Sample. There are NPL sites in 45 of the 48 continental states, highlighting that Superfund is genuinely a national program. However, the highest proportion of sites are in the Northeast and Midwest (i.e., the “Rust Belt”), which reflects the historical concentration of heavy industry in these regions.

Figures 2A and 2B present the geographic distribution of the 1982 HRS sample. Figure 2A displays the distribution of sites with initial HRS scores exceeding 28.5, while those with scores below this threshold are depicted in 2B. The sites in both categories are spread throughout the United States, but the below 28.5 sites are in fewer states. For example, there are not any below 28.5 sites in Florida and Arizona. The unequal distribution of sites across the country in these two groups is a potential problem for identification in the presence of the local shocks that are a major feature of the housing market. To mitigate concerns about these shocks, we will estimate models that include state fixed effects.

Figure 3 reports the distribution of HRS scores among the 490 sites in the 1982 HRS Sample. The figure is a histogram where the bins are 4 HRS points wide. The distribution looks approximately normal, with the modal bin covering the 36.5-40.5 range. Importantly, a substantial number of sites are in the “neighborhood” of the 28.5 threshold that determines eligibility for placement on the NPL. For example, there are 227 sites with 1982 HRS scores between 16.5 and 40.5. These sites constitute our regression discontinuity sample.

Figure 4 plots the mean estimated costs of remediation by 4 unit intervals, along with the fraction of sites in each interval with non-missing cost data. The vertical line denotes the 28.5 threshold. The non-zero mean costs below the threshold are calculated from the sites that received a score greater than 28.5 upon rescoring and later made it onto the NPL. The estimated costs of remediation appear to be increasing in the HRS score. This finding suggests that the 1982 HRS scores may be informative about relative risks. However, estimated costs are roughly constant in the neighborhood of 28.5 and this provides some evidence that risks are roughly constant among these sites.

IV. Econometric Methods

A. Least Squares Estimation with Data from the Entire U.S.

Here, we discuss the econometric models that we use to estimate the relationship between housing prices and NPL listing. We begin with the following system of equations:

(7) $y_{c90} = \theta\ 1(NPL_{c90}) + X_{c80}\,\beta + \varepsilon_{c90}, \qquad \varepsilon_{c90} = \alpha_c + u_{c90}$

(8) $1(NPL_{c90}) = X_{c80}'\Pi + \eta_{c90}, \qquad \eta_{c90} = \lambda_c + v_{c90},$

where y_{c90} is the log of the median property value in census tract c in 1990. The indicator variable $1(NPL_{c90})$ equals 1 only for observations from census tracts that contain a hazardous waste site that has been placed on the NPL by 1990. Thus, this variable takes on a value of 1 for any of the Superfund sites in column (1) of Table 1, not just those that were on the initial NPL list. The vector X_{c80} includes determinants of housing prices, measured in 1980, while ε_{c90} and η_{c90} are the unobservable determinants of housing prices and NPL status, respectively. We are also interested in the effect of NPL status in 2000, and the year 2000 versions of these equations are directly analogous.

A few features of the X vector are noteworthy. First, we restrict this vector to 1980 values of these variables to avoid confounding the effect of NPL status with "post-treatment" changes in these variables that may be due to NPL status. Second, we include the 1980 value of the dependent variable, y_{c80}, to adjust for permanent differences in housing prices across tracts and the possibility of mean reversion in housing prices.

Third in many applications of Rosen's model, the vector of controls, denoted by X, is limited to housing and neighborhood characteristics (e.g., number of bedrooms, school quality, and air quality). Income and other similar variables are generally excluded on the grounds that they are "demand shifters" and are needed to obtain consistent estimates of the MWTP function. However, if individuals treat wealthy neighbors an amenity (or disamenity), then the exclusion restriction is invalid. In the subsequent analysis, we are agnostic about which variables belong in the X vector and report estimates that are adjusted for different combinations of the variables available in the Census data.

The coefficient θ is the 'true' effect of NPL status on property values. For consistent estimation, the least squares estimator of θ requires $E[\varepsilon_{c90}\eta_{c90}] = 0$. If permanent ($\alpha_c$ and λ_c) or transitory (u_{c70} and v_{c70}) factors that covary with both NPL status and housing prices are omitted, then this estimator will be biased. In order to account for transitory factors, we report the results from specifications that include full sets of state fixed effects and county fixed effects to account for local shocks, respectively.

Ultimately, the approach laid out in equations (7) and (8) relies on a comparison of NPL sites to the rest of the country. The validity of this approach rests on the assumption that linear adjustment can control for all differences between census tracts with and without a NPL site. Further, it assumes that the placement on the NPL is not determined by future housing prices—this assumption will be invalid if, for example, gentrifying tracts are able to successfully lobby for the placement of a site on the NPL.

B.Instrumental Variables Estimation with the 1982 HRS Sample

Here, we discuss an alternative identification strategy that may solve the problems outlined above. This approach has two key differences with the one described above. First, we limit the sample to the subset of census tracts containing the 690 sites that were considered for placement on the initial NPL. Thus, all observations are from census tracts with hazardous waste sites that were initially judged to be among the nation's most dangerous by the EPA. If, for example, the β's differ across tracts with and without hazardous waste sites or there are differential trends in housing prices in tracts with and without these sites, then this approach will be the preferable. Second, we use an instrumental variables strategy to account for the possibility of endogenous rescoring of sites.

More formally, we replace equation (8) with:

(9) $1(NPL_{c90}) = X_{c80}'\Pi + \delta\, 1(HRS_{c82} > 28.5) + \eta_{c90}, \qquad \eta_{c90} = \lambda_c + v_{c90},$

where $1(HRS_{c82} > 28.5)$ is an indicator function that equals 1 for census tracts with a site that exceeds the 28.5 threshold, based on their HRS score from before the threshold was known. This approach exploits the variation in NPL status that is due to the site's 1982 HRS score.

For the IV estimator (θ_{IV}) to provide a consistent estimate of the HPS gradient, the instrumental variable must affect the probability of NPL listing without having a direct effect on housing prices. The next section will demonstrate that the first condition clearly holds. The second condition requires that the unobserved determinants of 1990 housing prices are orthogonal to the part of the 1982 HRS score that is not explained by X_{c80}. In the simplest case, the IV estimator is consistent if $E[1(HRS_{c82} > 28.5)\ \varepsilon_{c90}] = 0$.

We implement the IV estimator in two ways. First, we fit the IV estimator on the data from the 482 sites with nonmissing housing price data to obtain θ_{IV}. We also calculate IV estimates another way that allows for the possibility that $E[1(HRS_{c82} > 28.5)\ \varepsilon_{c90}] \neq 0$ over the entire sample. In particular, we exploit the regression discontinuity (RD) design implicit in the $1(\bullet)$ function that determines NPL eligibility. For example if $[1(HRS_{c82} > 28.5)\ \varepsilon_{c90}]=0$ in the neighborhood of the 28.5 threshold, then a comparison of housing prices in census tracts just above and below the threshold will control for all omitted variables. Consequently, our second IV estimator is obtained on the sample of 227 census tracts with sites that have 1982 HRS scores greater than 16.5 and less than 40.5. We also experiment with models that include the 1982 HRS score and its square in X_{c80}.

V. Empirical Results

A. Balancing of Observable Covariates

This subsection examines the quality of the comparisons that underlie the subsequent estimates. We begin by examining whether the $1(HRS_{c82} > 28.5)$ instrumental variable is orthogonal to the observable predictors of housing prices. While it is not a formal test of the exogeneity of the instrument, it seems reasonable to presume that research designs that meet this criterion may suffer from smaller omitted variables bias. First, designs that balance the observable covariates may be more likely to balance the unobservables (Altonji, Elder, and Taber 2000). Second, if the instrument balances the observables, then consistent inference does not depend on functional form assumptions on the relations between the observable confounders and housing prices. Estimators that misspecify these functional forms (e.g., linear regression adjustment when the conditional expectations function is nonlinear) will be biased.

Table 2 shows the association of $1(HRS_{c82} > 28.5)$ with potential 1980 determinants of housing prices. Columns (1) and (2) report the means of the variables listed in the row headings in the 184 and 306 census tracts with a hazardous waste sites with 1982 HRS scores below and above the 28.5 threshold with complete housing price data, respectively. Columns (3) and (4) report the means in the 90 and 137 tracts below and above the regulatory threshold in the regression discontinuity sample. Column (5) reports the means of the variables in the remaining 47,695 census tracts with complete housing price data. The remaining columns report p-values from tests that the means in pairs of the columns are equal. P-values less than .01 are denoted in bold.

Column (6) contrasts tracts containing sites with 1982 HRS scores exceeding 28.5 with the remainder of the US. The entries indicate that 1980 housing prices are 50% higher in the rest of the US. Further, the hypothesis of equal means can be rejected at the 1% level for 8 of the 12 demographic and economic variables. The difference in population density is large. Further, the fraction of the housing stock that is comprised of mobile homes is roughly more than 50% greater (0.0785 versus 0.0496) in tracts with hazardous waste sites exceeding the 28.5 threshold. Overall, it is evident the presence of a site with a HRS score exceeding 28.5 is correlated with many determinants of housing prices. It may be reasonable to assume that the estimation of equation (7) will produce biased estimates of the effect of NPL status.[27]

Column (7) compares the below and above 28.5 samples. The first two panels foreshadow the reduced form results. In particular, it is evident that $1(HRS_{c82} > 28.5)$ is highly correlated with NPL listing and that housing prices grow by more in the census tracts with a hazardous waste site with a HRS score exceeding 28.5.

[27] The results are similar when the tracts with NPL sites in the ALL NPL Sample are compared to the remainder of the US.

The differences in the potential determinants of housing prices are smaller than in the previous comparison. For example, the percentage of mobile homes is balanced across these two groups of census tracts. Notably, there are some important differences across the two sets of tracts. The mean housing price in 1980 is higher (although the median rent is nearly identical). Overall, the entries suggest that the above and below 28.5 comparison appears to reduce the potential for confounding.

Column (8) repeats this analysis for the regression discontinuity sample. The findings are remarkable in that the hypothesis of equal means in columns (4) and (5) cannot be rejected for a single one of the potential determinants of housing prices.

There is not enough room to present the results here, but there are substantial differences in the geographic distribution of sites across states in both the above and below 28.5 (i.e., columns 1 and 2) and regression discontinuity (i.e., columns 4 and 5) comparisons. This is a salient issue, because there were dramatic differences in state-level trends in housing prices in the 1980s and 1990s. Consequently, the most reliable specifications may be those that control for state fixed effects.

B. Least Squares Estimates with Data from the Entire U.S.

Table 3 reports the regression results of the fitting of 5 different versions of equation (7) for 1990 and 2000 housing prices. The entries report the coefficient and heteroskedastic-consistent standard error on an indicator variable for whether the census tract contains a hazardous waste site that was on the NPL at the time of the housing price observation. In panel A, the NPL indicator equals 1 for all NPL sites, while in Panel B the tract must contain a NPL hazardous waste site that received a 1982 HRS test. The intent of Panel B is to provide a baseline set of estimates for comparison with the subsequent quasi-experimental results from the 1982 HRS Sample.

All specifications control for the ln of the mean housing price in 1980, so the NPL indicator can be interpreted as the growth in housing prices in tracts with a NPL site relative to other tracts. The Column (4) specification includes state fixed effects to adjust for statewide shocks to housing prices. The Column (5) results are adjusted for a full set of county fixed effects. This specification will not be reliable if the NPL listing (and the ensuing clean-ups) affect neighboring census tracts. It is possible to think of stories where demand for housing in neighboring census tracts is increased and others where it is decreased, so it is not possible to sign any bias a priori. The exact covariates in each specification are noted in the row headings at the bottom of the table.

The results in Panel A demonstrate that NPL status is associated with increases in housing prices. Specifically, the estimates in the first row indicate that median housing prices grew by 6.3% to 14.9% (measured in ln points) more in tracts with a NPL site between 1980 and 1990. All of these estimates would be judged statistically significant by conventional criteria. The most reliable specification is probably the one with state fixed effects and this estimate is 9%.

The next row repeats this exercise, except for the growth of housing prices between 1980 and 2000. Here, the estimated effect of the presence of a NPL site within a tract's boundaries is associated with a 3% to 7% increase in the growth of house prices, depending on the specification. These estimates are all smaller than the ones from the comparable specifications in 1990, even though a higher fraction of the sites were further along in the clean-up process by 2000 (e.g., roughly half were construction complete by 2000). Notably, the standard errors on the 2000 estimates are roughly ½ the size of the 1990 standard errors. If omitted variables bias concerns are unfounded in this setting, then the larger 1990 effects are consistent with at least two possibilities: 1) the remediation process was proceeding more slowly than people's expectations at the sites where the clean-ups had not been completed; and 2) consumers' reduced their valuations of the clean-ups between 1990 and 2000.

The Panel B results are similar to those in Panel A. All of the estimates are statistically different from zero and imply that the placement of a site on the NPL is associated with a positive effect on the growth of housing prices. The 1990 estimates are also larger than the 2000 ones, which range from 4% to 7%. Recall, 60% of the sites in this sample were construction complete or deleted from the NPL by 2000.

Overall, Table 3 has presented the most comprehensive examination of the effect of the placement of hazardous waste sites on the NPL to date. All of the estimates are positive and suggest that by 2000 housing prices in tracts with a NPL site were 3%-7% higher than they would have been in the absence of the Superfund program. These results appear to convincingly reject the "stigma" hypothesis (see, e.g., Harris 1999) that placement on the NPL causes housing prices to decline. The next subsection probes the robustness of these findings.

C. Is the $1(HRS_{c82} > 28.5)$ a Valid Instrumental Variable for NPL Status?

This section presents evidence on the first-stage relationship between the $1(HRS_{c82} > 28.5)$ indicator and NPL status, as well as some suggestive evidence on the validity of the exclusion restriction. Figure 5 plots the probability of 1990 and 2000 NPL status by 4 unit bins of the 1982 HRS score. The figure presents dramatic evidence that a HRS score above 28.5 is a powerful predictor of NPL status in 1990 and 2000. Virtually all sites with initial scores greater than 28.5 scores are on the NPL. The figure also reveals that some sites below 28.5 made it on to the NPL (due to rescoring) and that this probability is increasing in the initial HRS score and over time.

Panel A of Table 4 reports on the statistical analog to these figures from the estimation of linear probability versions of equation (9) for NPL status in 1990 and 2000. In the first four columns, the sample is comprised of the 490 census tracts in the 1982 HRS Sample. In these columns, the sets of controls are identical to those in the first four columns of Table 3. In the fifth column, the sample is restricted to the regression discontinuity sample comprised of the 227 sites with HRS scores between 16.5 and 40.5. The controls are the same as in column (4). These specifications and samples are repeated throughout the remainder of paper.

The results confirm the visual impression that a 1982 HRS score above 28.5 increases the probability that a site is placed on the NPL. The point estimates imply a higher probability ranging between 68% and 87%, depending on the year and specification. Overall, these findings reveal a powerful first-stage relationship.

Panel B of Table 4 presents an informal test of the validity of our research design. The table reports the coefficient and standard error on the $1(HRS_{c82} > 28.5)$ indicator from four separate regressions, where the ln of 1980 mean census tract-level prices is the dependent variable. The specifications are identical to those in the upper panel (except, of course, they do not control for 1980 prices). Thus, these regressions test for differential 1980 housing prices above and below the threshold after adjustment for observed covariates. Residual housing prices may be an important predictor of the growth in housing prices, so evidence of significant differences might undermine the validity of our approach.

Across the specifications, the point estimate on the above 28.5 indicator is small both economically and statistically. Figure 6 allows for a more thorough investigation of this test. It takes the column (4) specification and replaces the constant and the $1(HRS_{c82} > 28.5)$ indicator with a full set of indicators for each 4 unit interval of the 1982 HRS score. The coefficients on these indicators represent the mean residual housing price in each bin, after adjustment for the observable covariates, and are plotted in the figure. There is little evidence of a pattern between residual housing prices and the 1982 HRS score. Importantly, this conclusion appears even more robust in the regression discontinuity sample, where the range of residual housing prices is small. Overall, this informal validity test fails to undermine the validity of the comparison of tracts with sites above and below the HRS threshold.[28]

D. Instrumental Variables Estimates of NPL Status on Housing Prices and Rental Rates

Table 5 presents the instrumental variables estimates of the effect of NPL status on housing prices from the 1982 HRS sample. We focus on the 2000 results initially. Across the five specifications of Panel A, the point estimates are in a remarkably narrow range. The estimates in the first four columns suggest that the placement of a hazardous waste site on the NPL causes house prices in that census tract to rise by 6.2%-6.9% (measured in ln points) between 1980 and 2000, relative to tracts with sites that narrowly missed placement on the NPL. These estimates would all be judged to be statistically different from zero at the 12% level or better, with the more precise estimates coming from the most robust specifications.

We also take advantage of the regression discontinuity design implicit in the rule for assigning sites to the NPL. Specifically, column (5) reports the results from fitting the column (4) specification with state fixed effects on the regression discontinuity sample. The point estimate is virtually unchanged

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[28] An analogous analysis of 1980 rental prices leads to similar conclusions.

by the discarding of more than half the sample, and this estimate has an associated p-value of approximately 0.13. When the 1982 HRS Score and its square are included in the column (4) specification with the full 1982 HRS sample, the point estimate is 0.046 with an associated standard error of 0.066. Overall, the 2000 estimates are strikingly similar to those from the All NPL Sample in Table 3.

The estimates from the primary 1990 regressions range from 4% to 12%. These estimates are poorly determined and none of them would be judged statistically significant at conventional levels. The regression discontinuity estimate is negative but the associated t-statistic is roughly 0.2. The most reasonable conclusion from these results is that there is little evidence that a site's placement on the NPL reduces 1990 housing prices in the site's census tract and that it is more likely than not that prices rise.

Figures 7 and 8 plot 1990 and 2000 residual housing prices, respectively, by 4 unit intervals of the 1982 HRS score. The estimates are adjusted for the column (4) covariates. The large jumps in the series are generally concentrated among the intervals with relatively few data points. Figure 8 reveals that the gains in housing prices are not concentrated among a few sites. Overall, this figure confirms that individuals valued the Superfund clean-ups.

Table 6 is exactly analogous to Table 5, except the dependent variables are 1990 and 2000 ln median rental rates. Rental units only accounts for roughly 20% of all housing units and generally differ on observable characteristics from owner occupied homes, so it may be appropriate to ignore this part of the housing market. The appeal of examining the rental market is that that rental rates are a flow measure so issues related to individuals' expectations about the length of time until clean-up can be ignored.

In 1990, the effect of NPL status from the primary specifications (i.e. columns 1 through 4) ranges from 0% to 5.6%, but none of the estimates statistically differ from zero. The 2000 results are more precise and the primary specifications suggest that NPL status caused an increase in rental rates. The most robust specification that controls for all statewide shocks to housing prices, implies that rental rates increased by 5.8%. In both years, the regression discontinuity estimates are negative but they are poorly determined and have associated t-statistics less than 0.75. Overall, the rental rates provide some support for the notion that by 2000 NPL status is associated with higher prices in the housing market.

Table 7 presents separate two stage least squares estimates of the effect of the different stages of the remediation process on 1990 and 2000 housing prices. The three endogenous variables are separate indicator variables for tracts that contain a site that by 1990/2000: is on the NPL but a ROD has not been issued; has a ROD and/or clean-up has been initiated but not completed; or, has been designated construction complete or deleted from the NPL. Importantly, these categories are mutually exclusive, so each of the tracts with a NPL site only helps to identify one of the indicators. The three instruments are the interaction of the $1(HRS_{c82} > 28.5)$ variable with indicators for deletion from the NPL, the construction complete designation, and on the NPL but neither construction complete nor deleted.

The purpose of this exercise is to test whether the effect on housing prices varies with the different stages of the remediation process. The table reports the point estimates and their standard errors, along with the p-value from a F-test that the three point estimates are equal. The number of sites in each category and the mean HRS score is also listed in brackets.

We focus on the 2000 results, since only 16 sites are in the "Construction Complete or NPL Deletion" category in 1990. The point estimates for this category are all positive and imply an estimated increase in housing prices ranging from 4.2% to 6.8%. All of the estimates, except the one from the column one specification, would be judged to differ from zero at the 10% level or better. The "ROD and Incomplete Remediation" category's point estimates in the housing price regressions are all positive but the null of zero cannot be rejected in the more robust specifications in columns (4) and (5).

The sites in the "NPL Only" category provide a compelling opportunity to further explore the possibility that a site's placement on the NPL leads to price declines, because the EPA has not even announced a remediation plan yet. The 1990 results are the most useful to explore this question, because 96 sites were in this category in 1990. These point estimates fail to provide much evidence in favor of an initial price decline as 4 of the 5 estimates are positive, although all of them are poorly determined. Overall, the results in Table 7 are consistent with the notion that housing prices rise as the site progresses through the

Table 8 reports the IV results of the effect of NPL listing on property values in census tracts that neighbor the tracts in the 1982 HRS sample. The dependent variable is the ln of the mean of housing prices across all neighboring tracts. In panel A, neighbors are defined as any census tract that shares a border with the tract containing the hazardous waste site. In panels B and C, neighbors are the portion of census tracts that fall within 1 and 2 mile distance rings around the primary census tract's borders. The aggregate value of the housing stock in 1980 in the different neighbor groups is $600 million, $850 million, and $1,650 million (all in 2000 $'s), respectively. The Data Appendix provides further details on how we implemented these definitions of neighbors.

The Panel A estimates are all positive. The 2000 results imply an increase in the median housing values that ranges between 4% and 10% and generally would not be considered statistically significant at the conventional 5% level. The estimate from the column (4) specification that includes state fixed effects is about 6% and zero can be rejected at the 7% level. Interestingly, the regression discontinuity estimate is similar in magnitude, although it is less precisely estimated. The evidence from this definition of neighbors is not overwhelming, but it appears to suggest that median house prices rose in the census tracts that neighbor tracts with sites placed on the NPL, relative to the neighbors of tracts with sites that narrowly missed placement on the NPL. Overall, these results provide further evidence that Superfund clean-ups are valued in the housing market.

Panels B and C rely on broader definitions of neighbors. The 2000 point estimates are all positive but of a much smaller magnitude. The implication is that as the definition of neighbors is enlarged the positive price effect disappears. This finding seems sensible in light of the relatively small size of most NPL sites.

E. Does NPL Status Affect the Total Population and Demographics?

Table 9 estimates IV models for a series of demographic variables with the same five specifications. The intent is to determine whether NPL status affects the total population of the site's census tract and the demographics of its residents by 2000. This exercise can be considered a test of whether individuals sort in response to changes in environmental amenities.

The most robust finding is the substantial increase in housing units and population in NPL tracts. Specifically, the columns (1) – (4) estimates suggest that the number of housing units increased by roughly 140 units between 1980 and 2000 and that total population in these tracts increased by approximately 325. The regression discontinuity estimates for these outcomes are imprecise but fail to contradict the findings in the other specifications.

Panels B and C explore whether residents in 2000 are wealthier. The fraction of households receiving public assistance appears to decline. There is also modest evidence of a relative increase residents' educational levels. For readers interested in the environmental justice literature (Citation to come), there is no evidence that the fraction of Blacks or Hispanics changed meaningfully.

VI. Interpretation

This paper's results allow for a preliminary cost-benefit analysis of the clean-up of a hazardous waste site. To conduct this analysis, we utilize the column (4) estimates from 2000 for the site's tract and its neighbors from Tables 5 and 8. These estimates are adjusted for state fixed effects in changes in housing prices. Both of these estimates implied a relative gain in housing values of approximately 6%.[29]

The 1980 mean of aggregate property values in tracts with hazardous waste sites placed on the NPL is roughly $75 million (2000 $'s). This implies that property values were about $4 million higher by 2000 in these tracts due to the placement of the site on the NPL. In the neighboring census tracts, the mean of aggregate property values is about $600 million, so the aggregate increase in property values is roughly $36 million. These calculations suggest an overall increase in property values of roughly $42 million.

It is natural to compare the gain in property values to the costs of clean-up. The mean expected costs of clean-ups are roughly $28 million. Table 1 suggests that expected costs understate the actual costs by roughly 50%, so a more appropriate estimate of the costs of clean-up is approximately $42

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[29] Recall, the column (4) estimate from Panel B of Table 3 is 5%. This estimate is obtained from all US census tracts, rather than the 1982 HRS sample. Some readers will prefer the point estimates from alternative specifications and the subsequent calculations will naturally be affected by these choices

million. Strangely, this measure of costs is essentially equivalent to the increase in property values, so these calculations imply that the benefits of the Superfund program are roughly equal to its costs.

There are at least four caveats to this crude cost-benefit analysis. First, in light of the finding in Table 7 that the gain in property values is greater in tracts where remediation efforts are finished, it may be reasonable to expect this measure of the benefits of the Superfund program to increase as remediation is completed at the 40% of sites in the 1982 HRS sample where these efforts were still ongoing as of 2000. Second, the benefits measure is based on the assumption that housing markets perfectly capitalize the value of any improvements in health (and aesthetics) associated with the clean-ups. To the extent that individuals' expectations about the health gains are too small or too large, it may be appropriate to adjust the benefits measure up or down. Third, we suspect (but are uncertain) that our cost measures exclude the EPA's costs of administering the program. Further, they certainly exclude the deadweight loss associated with the collection of funds through the tax system. Thus, the costs per clean-up may be understated. Fourth, we would be remiss to fail to remind the reader that the estimated effects of NPL status on property values were estimated with more imprecision than we consider ideal for making policy recommendations

VI. Conclusions

To Come.

DATA APPENDIX

I. Assignment of HRS Scores

The HRS test scores each pathway from 0 to 100, where higher scores indicate greater risk.[30] Each pathway score is capped at 100.[31] The individual pathway scores are calculated using a method that considers characteristics of the site as being included in one of three categories: waste characteristics, likelihood of release, and target characteristics. The final pathway score is a multiplicative function of the scores in these three categories. The logic is, for example, that if twice as many people are thought to be affected via a pathway then the pathway score should be twice as large.

The final HRS score is calculated using the following equation:

(1) HRS Score $= [(S^2_{gw} + S^2_{sw} + S^2_{a}) / 3]^{½}$,

where S_{gw}, S_{sw}, and S_{a}, denote the ground water migration, surface water migration, and air migration pathway scores, respectively. As equation (1) indicates, the final score is the square root of the average of the squared individual pathway scores. It is evident that the effect of an individual pathway on the total HRS score is proportional to the pathway score.

It is important to note that HRS scores can't be interpreted as strict cardinal measures of risk. A number of EPA studies have tested how well the HRS represents the underlying risk levels based on cancer and non-cancer risks.[32] The EPA has concluded that the HRS test is an ordinal test but that sites with scores within 2 points of each pose roughly comparable risks to human health (EPA 1991).[33]

II. Primary Samples

We have two primary samples. The first sample includes sites that were placed on the National Priority List (NPL) before January 1, 2000. There are 1,436 sites in this sample. The second sample is all sites that were tested between 1980 and 1982 for inclusion on the initial National Priority List announced on September 8, 1983.

A. All NPL Sample

The all NPL sample only includes National Priority List sites located in US states and does not include sites that were proposed for but not listed on the NPL before January 1, 2000. As noted in the text, we use census tract data from the 1980, 1990, and 2000 year US Census reports. Although there are NPL sites located in US territories such as Puerto Rico, we do not include these in the sample because the same census data are not available for US territories. Further we only include sites in the sample that were listed on the NPL before January 1, 2000 to ensure that site listing occurred before any data collection for the 2000 census.

B. 1982 HRS Sample

The second sample consists of sites tested for inclusion on the initial NPL published on September 8, 1983. 690 sites were tested for inclusion on this list. As noted in the text, not all sites tested between 1980 and 1982 were placed on the first NPL list due to initial HRS scores below 28.5.

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[30] See the EPA's *Hazard Ranking System Guidance Manual* for further details on the determination of the HRS score.

[31] The capping of individual pathways and of attributes within each pathway is one limiting characteristic of the test. There is a maximum value for most scores within each pathway category. Also, if the final pathway score is greater than 100 then this score is reduced to 100. The capping of individual pathways creates a loss of precision of the test since all pathway scores of 100 have the same effect on the final HRS score, but may represent different magnitudes of risk.

[32] See Brody (1998) for a list of EPA studies that have examined this issue.

[33] The EPA states that the HRS test should not be viewed as a measure of "absolute risk", but that "the HRS does distinguish relative risks among sites and does identify sites that appear to present a significant risk to public health, welfare, or the environment" (Federal Register 1984).

Additionally, 12 sites proposed for the NPL on December 30, 1982 were not listed on the first NPL which was issued on September 8, 1983. Specifically, 418 sites were proposed for the NPL, while 406 sites were listed. The difference between the proposed list and the final list is due mostly to the rescoring of sites. The EPA received 343 comments on 217 sites (all of which were proposed NPL sites) that led to score changes in 156 sites. Revised scores for 5 of these sites fell below 28.5. These sites were dropped from the proposed list. Also not included on the 1983 NPL are 7 more sites. These 7 sites were considered "still under consideration" and did not have final rescores available as of September 8, 1983.

Here is a detailed explanation of the difference between the 1982 proposed list and the first NPL issued in 1983:

(1) Included on the 1982 proposed list and not on 1983 final list

- a. Sites with a revised HRS score below 28.5:
  1. Crittenden County Landfill (Marion, AR)
  2. Flynn Lumber (Caldwell, ID)
  3. Parrot Road (New Haven, IN)
  4. Phillips Chemical (Beatrice, NE)
  5. Van Dale Junkyard (Marietta, OH)
- b. Sites "still under consideration":
  1. Clare Water Supply (Clare, MI)
  2. Electravoice (Buchanan, MI)
  3. Littlefield Township Dump (Oden, MI)
  4. Whitehall Wells (Whitehall, MI)
  5. Kingman Airport Industrial Area (Kingman, AZ)
  6. Airco (Calvert City, KY)
  7. Bayou Sorrel (Bayou Sorrel, LA)
- c. State priority sites that were dropped:
  1. Plastifax (Gulfport, MS)
- d. Sites cleaned up by the responsible party before the 1983 NPL:
  1. Gratiot Co Golf Course (St. Louis, MI)
- e. Sites split into two separate sites:
  1. Vestal Water Supply (Vestal, NY)

(2) Included on the 1983 final list but not on the 1982 proposed list

- a. Two separate sites, formally Vestal Water Supply:
  1. Vestal 1-1 (Vestal, NY)
  2. Vestal 4-2 (Vestal, NY)
- b. Site identified and tested after the 1982 proposed list:
  1. Times Beach (Times Beach, MO)

Note that 5 of the 7 "still under consideration" sites (Airco, Bayou, Clare, Electravoice, Whitehall Wells) were later added to the NPL. All five sites had score changes (3 revised upward, 2 revised downward). Two sites (Littlefield, Kingman) were never listed on the NPL. These sites would have had scores that dropped below 28.5. For consistency, we included the score changes for the 5 sites that were later placed on the NPL under the 1983 score variable in the dataset. However, as described above, these scores were not actually released along with the other score changes in 1983.

Changes to site status for the sites in (1)c-(1)e, (2)a, and (2)b above did affect our sample. Gratiot Co Golf Course (1)d was remediated before publication of the final NPL and therefore dropped from our sample. The original Vestal Water Supply (1)e split into 2 sites, with Vestal 4-2 retaining all of the original attributes of the site. We therefore considered Vestal 4-2 as a continuation of the original site. Vestal 1-1 is not included in our sample as there is no 1982 score associated with this site. Likewise Times Beach (2)b is not included in our sample since there is no 1982 score. Plastifax (1)c received a 1982 score that would not have qualified the site for remediation. The site remains in the sample as would any other site that scored below 28.5.

Finally as discussed in the text we use the 1982 HRS score as an instrument for NPL status. Therefore, the score changes do not effect how we treat each site provided the site received an initial score for the 1982 proposed list.

III. Site Size Variable

The size of site is taken directly from EPA documentation on the site. Note that there are two sources for the "actual physical size" of a superfund site. Both sources are from the EPA's on-line CERCLIS system. In our data files we designate 'size_fs' as the size of the site in acres extracted from the Fact Sheet and 'size_sn' as the size of the site in acres extracted from the Site Narrative. They are frequently different. For these sites we used the average of the two sources. If only one was available we used that one.

Note that is sometimes the case that the site size provided in CERCLIS refers to the area of source of the contamination and not the size of the site. There are relatively few sites that are described this way. To maintain consistency in how we interpret a site's size we excluded these data from our primary data file and indicated the 'actual-size' as missing. Further, there are some sites for which there is no size data available in CERCLIS. It is possible that we may be able to fill in size data for some of these sites using the original HRS scoring sheets. We have requested many of these sheets from the EPA docket center via a Freedom of Information Request.

Finally, sometimes the source of contamination is described as being just one part of the entire site. For example, the description for superfund site: NJD980505424 says that there is a 57 acre landfill on 144 acres of property. For this site and others like this we considered the physical size of the site to be 57 acres.

IV. Measures of Expected and Actual Remediation Costs

We collected data on the expected and actual costs of remediation at each Superfund site in our samples. Here, we describe the differences in these measures of costs and how they were calculated.

A. Expected (Estimated) Costs

The expected cost data is taken directly from the first ROD for each site (note that the EPA refers to these as estimated costs). Each ROD evaluates possible remedial action plans and selects one that satisfies all relevant national and state requirements for human health and the natural environment. RODs are issued for NPL sites only, so expected costs are unavailable for sites that fail to make it onto the NPL.

Estimated costs include both the remedial action cost and where available the discounted operations and management cost for the selected remedy. The projected time period for these operation and management costs is usually 20-30 years. All estimated costs are adjusted for year 2000 $'s using the Consumer Price Index.

Many sites have multiple "operating units" or completely separate sections of the site with different Records of Decision. We include estimated costs from each "operating unit" that has a separate Record of Decision. Savannah Silver Site is the site with the greatest number of operating units included in our sample with at least 73. Many of these operating units do not yet have a published Record of Decision with an estimated cost. The vast majority of sites—approximately 90%—have 3 or less operating units.

Note that the Savannah Silver Site highlights a limitation of the expected cost data. Many sites listed on the National Priority List have Records of Decision and expected costs available for some, but not all of the operating units at the site. To guard against the possibility of under-estimating the expected costs at a site we emphasize expected cost data from those sites that are construction complete. It is clear that all Records of Decision would be published for these sites.

Occasionally sites or "operating units" at a site have updated Records of Decision with new estimated costs. These updates are not included as part of the expected costs we present in this paper. Thus, the interpretation of the expected costs in this paper is that they are a projected total cost of site remediation before remedial cleanup action begins at the site. We did calculate expected costs for sites that included all updates from subsequent Records of Decision. Approximately one quarter of the sites have amended cost estimates. These updated costs, on average, are remarkably similar to the expected costs that only include initial cost estimates. For sites with non-missing data in our 1982-3 sample the mean expected costs for the 1st Record of Decision only and all relevant Records of Decision, conditional on construction complete, are 20.6 and 20.3 million respectively. For sites with non-missing data in the all NPL sample these estimates are 15.5 and 14.8 million.

B. Actual Costs

The actual cost data presented in this paper is our best effort to calculate the actual amount spent on remedial action at each site by the EPA, state governments, and responsible parties. As will be explained in greater detail below, the actual cost data comes from 2 sources. The first source is a complete history of all EPA costs summarized by year and site. These data were provided to us by the financial/accounting department at the federal EPA office. The second source is a document called *Enforcement 3*, also obtained from the accounting department of the national EPA, which estimates all potential responsible party (i.e. private party) costs for each National Priority List site. These potential responsible party (PRP) costs are estimates by EPA engineers of remedial action expenses paid directly by companies and individuals. These costs are not reimbursements to the EPA or another party for work that was already completed. Note that private companies are not required to disclose the actual amount of money spent on remediation efforts. The actual cost data used in this paper is the sum of the EPA actual costs and the PRP estimated costs.

Before explaining in greater detail the data sources used, we should note that we explored the use of two other data sources for actual cost, but we were uncomfortable with the quality of these data. The first source was a data file sent to us by the National EPA office that reportedly included all available actual cost data on National Priority List sites. However, on inspection of this file there were many cases of sites with actual cost amounts of 1, 0, and negative dollar amounts respectively. Our hypothesis is that these data include money reimbursed to the EPA by states and potential responsible parties. This could account for the negative and zero dollar amounts for sites that clearly had remedial action. We are uncertain as to what might explain the arbitrarily low dollar amounts (1, 2, etc.) other than data error. The second source of data we explored using is the "actual cost" figures listed for some National Priority List sites on the EPA's Superfund website (CERCLIS). On inspection of these cost figures we again found 1, 0, and negative dollar amounts.

Apart from the obvious concerns with the other potential actual cost data sources there are several advantages of the data provided to us by the financial office of the EPA. First, the costs are all listed by site by year. This allows us to adjust all cost expenditures to year 2000 $'s. Second, the EPA actual cost data include both 'direct' and 'indirect' costs for each site. Direct costs include remedial action and operations and management costs. Indirect costs are the EPA's estimate of the portion of the Superfund program costs (personnel wages, travel costs to inspect the sites, etc.) that are attributed to each site. Third, by including EPA estimates for additional Potential Responsible Party costs we have a more complete accounting of the total costs to remediate each site.

However, despite our best efforts there are still 2 challenges regarding the actual cost data reported in this paper. First, to our knowledge, this is the first time that cost data from the accounting office has been directly linked with other site descriptive data. One surprising difficulty has been simply merging the two data sets. The site id numbers used by the financial office at the EPA are different from the site id numbers used by EPA's electronic database CERCLIS. To date neither the financial office at the EPA nor the individuals who work with the data in CERCLIS have been able to provide information that links these two site ids. We have been able to match approximately half of the sites on name alone. These are the actual cost data provided in this paper.

A second challenge regarding the actual cost data is how to interpret potential state costs. Initial Superfund legislation required that state governments pay for at least 10% of the remedial costs for sites located in their state along with all of the operations and management costs. The Federal EPA does not track state costs. Conversations with federal EPA personnel have indicated that it is often the case that the Federal EPA pays for the work done at the sites and that the states then reimburse the EPA. This interpretation would be consistent with the fact that the EPA actual cost data file tracks operations and management costs—costs technically supposed to be covered by the states. However, it is likely that there are additional state costs that should be included as part of a state's total actual cost of remediation. It is entirely possible that the actual cost figures presented in this paper under-represent the real actual cost of remediation by approximately 10%. We are currently attempting to contact individual states so as to obtain complete state cost information on all of the sites in our samples. We are also trying to obtain figures for state reimbursement costs from the EPA.

V. Placing Hazardous Waste Sites in a 2000 Census Tract

The census tract is used as a unit analysis because it is the smallest aggregation of data that is available in the 1980, 1990 and 2000 US Census. As noted in the text, year 2000 census tract boundaries are fixed so that the size and location of the census tract is the same for the 1980 and 1990 census data. The fixed census tract data were provided by Geolytics, a private company. More information on how the 1980 and 1990 census tracts were adjusted to fit the 2000 census tract boundaries can be found on their website at: www.geolytics.com.

There are 2 types of hazardous waste sites in our sample—those that were eventually listed on the National Priority List (NPL) and those that have never been listed on the NPL. We placed both types of hazardous waste sites in our sample in a single census tract. The remainder of this section describes the separate procedures we used to determine the year 2000 census tract of location for NPL and non-NPL hazardous waste sites.

For the NPL sites, latitude and longitude coordinates are available on the EPA summary page (CERCLIS site page). These coordinates were spot checked against their addresses and site descriptive information. GIS Arc Map software was then used to place these sites in a single census tract.

It is more difficult to place the hazardous waste sites that have never been on the NPL in a single census tract. Our first attempt was to place these sites using a comprehensive file provided to us by the EPA that contained latitude and longitude coordinates for non-NPL sites. However, upon inspection of this file we found numerous errors. Many of our sample sites were placed in different cities, counties, states, or zip codes from the EPA address descriptions provided in CERCLIS and the Federal Register.

In light of the unreliable latitude and longitude data we have used several methods to place these sites. Those sites with complete street address information were placed using a program that converts street addresses to latitude and longitude coordinates. These coordinates were then placed in a census tract using GIS Arc Map software.

Those non-NPL sites with missing or incomplete addresses were the most difficult sites to place. We requested original Hazardous Ranking System (HRS) documents on all of these sites from the Federal Register. The HRS documents are the first comprehensive documents prepared for each site. These documents often contain more detailed descriptive information on the sites. Some HRS documents also contain maps showing a site's location in the surrounding community. Many of these sites could be placed by hand using the more detailed descriptive and location information contained in the HRS documents and an electronic US Census map.

We called regional and state EPA officials regarding all non-NPL sites for which we were not able to place with certainty using either CERCLIS information or the HRS scoring packages. For most of these sites we were able to locate someone with 1st hand knowledge of the site or who was able to provide us with either a map of the site, a more complete address, or more accurate latitude longitude coordinates. As of Febuary 2005, there are 4 sites from the 1982-3 sample that could not be placed in a census tract.[34]

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[34] For example, we were unable to place Diamond Shamrock Chromate Plant Landfill in a single census tract. The only address in all EPA documents and the Federal Register is "South of Ohio 535, Fairport Harbor, Ohio." There are at least 6 census tracts that fit this description and conversations with state and regional EPA officials failed to yield more precise information. Consequently, this site was dropped from the analysis.

There are 8 other sites that are included in our sample for which we still need further information to verify that the census tract being used is correct.

Finally, there is at least one issue raised by using the multiple methods to place the hazardous waste sites. All sites placed via latitude and longitude coordinates are by design, placed in a single census tract. However, some of these sites may actually be at the intersection of multiple sites. This possibility became apparent when placing the other sites by hand. Occasionally (EXACT NUMBER TO COME) the address listed for a site is on the boarder of multiple census tracts. This is most often the case for sites that are at the intersection of streets also used to define census tract boundaries. For these sites, one of the intersecting census tracts was used at random and the other census tract(s) was recorded as an alternative census tract. In the next version of this paper, we will test whether the results are sensitive to this choice of the census tract**.**

VI. Neighbor Samples

Each superfund site in our sample is placed in a single census tract. Unfortunately, we have not been able to exactly place each site within its census tract using a precise address or reliable latitude longitude coordinates. This is particularly true for many of the non-NPL sites from the 1982-3 sample.

The effect of knowing the census tract, but not the precise location within the census tract for all of our sample sites poses a challenge for our analysis. Our hypothesis is that the effect of a cleanup of superfund site on the price of housing will decrease as the distance from the site increases. Further, the effected housing stock may extend beyond the site's census tract. The chief difficulty with examining this possibility is that we do not know the precise location of each sample site within their census tract. Consequently, we use two approaches to define the set of houses outside the sites' tract that may be affected by the clean-up. We refer to this set as "neighbors."

The first approach defines the neighbors as all census tracts that share a border with the tract that contains the site. GIS software was used to find each primary census tract and extract the fips codes of the adjacent neighbors. In the 1982-3 sample the maximum number of neighboring census tracts is 21 and the median is 7. The population of each adjacent census tract was used to weight the housing price, housing characteristics, and demographic variables for each tract when calculating the mean adjacent neighbor values.

The second approach defines neighbors based on distance 'rings' around the primary census tract. GIS software is used to draw a 'ring' around the primary census tract of a specified distance from each point on the boundary of the census tract. For example, in the 1 mile sample, a GIS program calculates a 1 mile perpendicular distance away from the census tract at each point on the boundary of the census tract. The collection of these points forms a 1 mile 'ring' around the original census tract. Data from all census tracts that fall within this 'ring' are used in calculating the mean housing values and housing and demographic characteristics for all housing within 1 mile of the primary census tract. Each census tract is weighted by the product of the population and the portion of the total area of each census tract that falls within the 'ring.' The maximum number of census tracts included in the 1 mile ring for a site is 54 and the median is 10. For the 2 mile ring the maximum number of neighbor sites is 126, with a median of 13.

We are still exploring data sources in hopes of obtaining exact location information on each site in our sample so as to draw 'rings' around the site itself rather than the site's census tract. We have requested, via the Freedom of Information Act, primary data and summary sheets on many of sites for which the exact location is uncertain. We have also contacted EPA state and regional personnel as well as state and local non-EPA officials in an effort to locate individuals with firsthand knowledge of the earlier sites.

Finally, we are experimenting with GIS code that draws a 'ring' around the centroid of each site's census tract. This method might be preferable as it would help control for the size of the primary census tract. That is, those site's located in large census tracts would be more likely to be farther away from the census tract's boundary. By drawing a ring that has as its center the centroid of the census tract, the distance from the centroid to the boundary will be greater for larger census tracts and thereby approximate the effect that it would have on having fewer census tracts within the specified distance. The results from this method are still incomplete.

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MANY MORE TO COME:

Table 1: Summary Statistics on the Superfund Program

	All NPL Sample w/ Complete House Price Data	1982 HRS Sample w/ Complete House Price Data	1982 HRS Sample w/ Missing House Price Data
	(1)	(2)	(3)
Number of Sites	984	490	184
1982 HRS Score Above 28.5	------	306	95
A. Timing of Placement on NPL			
Total	984	330	111
# 1981-1985	406	310	97
# 1986-1990	443	16	11
# 1991-1995	73	2	1
# 1996-1999	62	2	2
B. HRS Information			
Mean Score | HRS $\geq$ 28.5	42.74	44.47	43.23
Mean Score | HRS < 28.5	-----	15.47	16.50
C. Size of Site (in acres)			
Number of sites with size data	928	310	97
Mean	1,205	334	10,508
Median	29	25	35
Max	198,400	42,560	405,760
D. Stages of Clean-Up for NPL Sites			
Median Years from NPL Listing Until:			
ROD Issued	------	4.1	4.0
Clean-Up Initiated	------	5.8	6.8
Construction Complete	------	12.1	11.5
Deleted from NPL	------	12.8	12.5
1990 Status Among Sites NPL by 1990			
NPL Only	387	95	31
ROD Issued or Clean-up Initiated	330	213	68
Construction Complete or Deleted	26	16	7
2000 Status Among Sites NPL by 2000			
NPL Only	128	13	3
ROD Issued or Clean-up Initiated	374	119	33
Construction Complete or Deleted	479	198	75
E. Expected Costs of Remediation (Millions of 2000 $'s)			
# Sites with Nonmissing Costs	756	289	94
Mean	27.8	27.6	29.7
Median	10.3	14.8	10.8
Mean | Construction Complete	14.7	20.6	17.3
F. Actual and Expected Costs Conditional on Construction Complete (Millions of 2000 $'s)			
Sites w/ Both Costs Nonmissing	439	171	55
Mean Costs:			
Expected	15.3	21.5	16.8
Actual	21.0	33.9	23.7

Median Costs:			
Expected	7.8	10.3	6.7
Actual	11.0	16.6	8.5

Notes: All dollar figures are in 2000 $'s. The EPA's 1st Record of Decision for each "operating unit" at a site is the source of the estimated cost information.

Table 2: Mean Census Tract Characteristics by Categories of the 1982 HRS Score

	HRS < 28.5	HRS > 28.5	HRS > 16.5 & < 28.5	HRS > 28.5 & < 40.5	Rest of US	P-Value (2) vs. (5)	P-Value (1) vs. (2)	P-Value (3) vs. (4)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# Census Tracts	184	306	90	137	47,695	-----	-----	-----
Superfund Clean-up Activities								
Ever NPL by 1990	0.1196	0.9869	0.2111	0.9854	-----	-----	**0.0000**	**0.0000**
Ever NPL by 2000	0.1522	0.9869	0.2556	0.9854	-----	-----	**0.0000**	**0.0000**
Housing Prices								
1980 Mean	45,918	52,137	45,635	50,648	68,967	**0.0000**	**0.0064**	0.0573
1990 Median	80,317	96,752	85,991	91,611	99,160	0.5464	0.0053	0.5455
2000 Median	114,070	135,436	116,700	123,503	150,700	**0.0001**	**0.0003**	0.3983
Housing Rents								
1980 Median	218	226	218	218	216	0.0852	0.4169	0.9491
1990 Median	441	469	446	444	448	0.1094	0.1654	0.9431
2000 Median	584	670	607	593	679	0.5076	**0.0001**	0.6354
Demographics & Economic Characteristics								
Population Density	1,524	1,157	1,488	1,151	5,389	**0.0000**	0.1103	0.3769
% Black	0.1208	0.0713	0.0893	0.0844	0.1163	**0.0000**	0.0147	0.8606
% Hispanic	0.0490	0.0424	0.0365	0.0300	0.0716	**0.0000**	0.5092	0.5049
% Under 18	0.2947	0.2936	0.2939	0.2934	0.2796	**0.0000**	0.8401	0.9620
% Female Head HH	0.1910	0.1576	0.1689	0.1664	0.1894	**0.0000**	**0.0084**	0.8665
% Live Same House 5 Years Ago	0.5998	0.5623	0.5858	0.5655	0.5154	**0.0000**	**0.0020**	0.2318
% 16-19 Drop Outs	0.1596	0.1339	0.1491	0.1343	0.1361	0.7025	0.0202	0.2740
% > 25 No HS Diploma	0.4036	0.3429	0.3801	0.3533	0.3148	**0.0003**	**0.0000**	0.1548
% > 25 BA or Better	0.1029	0.1377	0.1138	0.1343	0.1742	**0.0000**	**0.0000**	0.1013
% Unemployed	0.0882	0.0712	0.0753	0.0734	0.0658	0.0203	**0.0002**	0.7305
% < Poverty Line	To Come	To Come	To Come	To Come	To Come	To Come	To Come	To Come
% Public Assistance	0.0935	0.0745	0.0835	0.0755	0.0763	0.6340	**0.0077**	0.3842
Average HH Income	19,280	20,869	19,610	20,301	21,501	0.0579	**0.0030**	0.3518
Housing Characteristics								
Total Housing Units	1,354	1,353	1,372	1,319	1,349	0.9072	0.9800	0.5390
% Owner Occupied	0.6750	0.6800	0.6920	0.6730	0.6196	**0.0000**	0.7586	0.4060
% 0-2 Bedrooms	0.4682	0.4439	0.4584	0.4496	0.4680	0.0131	0.1249	0.6997
% 3-4 Bedrooms	0.5100	0.5284	0.5159	0.5200	0.5055	0.0122	0.2240	0.8489

% 5+ Bedrooms	0.0215	0.0269	0.0256	0.0289	0.0265	0.7558	**0.0075**	0.3398
% Built Last 5 Years	0.1143	0.1404	0.1299	0.1397	0.1545	0.0455	0.0180	0.5357
% Built Last 10 Years	0.2271	0.2814	0.2559	0.2758	0.2888	0.4887	**0.0017**	0.3991
% Built Before 1950	0.3905	0.3128	0.3507	0.3295	0.3173	0.6993	**0.0002**	0.4285
% No Full Kitchen	0.0234	0.0188	0.0262	0.0222	0.0174	0.3969	0.1215	0.4452
% Heat is Fireplace, Stove, Portable, None	0.0575	0.0516	0.0689	0.0546	0.0436	0.0721	0.4414	0.2501
% No Air Conditioning	0.5188	0.4801	0.5323	0.5103	0.4274	**0.0002**	0.0821	0.4996
% with Zero Full Baths	0.0346	0.0259	0.0382	0.0290	0.0230	0.1102	0.0166	0.1411
% Units Detached	0.8567	0.8908	0.8541	0.8897	0.8791	0.1331	0.0428	0.1249
% Units Attached	0.0660	0.0307	0.0600	0.0317	0.0713	**0.0000**	0.0180	0.1670
% Mobile Homes	0.0773	0.0785	0.0859	0.0787	0.0496	**0.0000**	0.9117	0.6195

Notes: Columns (1) - (5) report the means of the variables listed in the row headings across the groups of census tracts listed at the top of the columns. In all of these columns, the sample restriction that the census tract must have nonmissing house price data in 1980, 1990, and 2000 is added. Columns (6)-(8) report the p-values from tests that the means in different sets of the subsamples are equal. P-values less than .01 are denoted in bold. For the heat, air conditioning, and bath questions, the numerator is year round housing units and the denominator is all housing units. For all other variables in the "Housing Characteristics" category, the denominator is all housing units.

Table 3: Estimates of the Association Between Presence of a NPL Hazardous Waste Site and the ln of Median Census Tract Housing Prices and Rental Rates, 1990 and 2000

	(1)	(2)	(3)	(4)	(5)
	A. Ever NPL				
Ln (1990 Median Price)					
1(NPL Status by 1990)	0.118	0.146	0.149	0.089	0.063
	(0.023)	(0.021)	(0.020)	(0.018)	(0.016)
Ln (2000 Median Price)					
1(NPL Status by 2000)	0.038	0.043	0.069	0.059	0.027
	(0.012)	(0.011)	(0.010)	(0.009)	(0.007)
	B. 1982 HRS Sample and Ever NPL				
Ln (1990 Median Price)					
1(NPL Status by 1990)	0.119	0.133	0.135	0.053	0.054
	(0.032)	(0.029)	(0.029)	(0.025)	(0.023)
Ln (2000 Median Price)					
1(NPL Status by 2000)	0.068	0.069	0.077	0.049	0.035
	(0.016)	(0.015)	(0.014)	(0.013)	(0.010)
1980 Prices	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
County Fixed Effects	No	No	No	No	Yes

Notes: The table reports results from 20 separate regressions where the unit of observation is a census tract. The dependent variables are underlined in the first column. The table reports the regression coefficient and heteroskedastic consistent standard error (in parentheses) associated with the indicator variable for whether the census tract contains a hazardous waste site that has been placed on the NPL by 1990 (2000). In Panel B, the value of these indicator variables is equal to one if the tract contains a site that was on the NPL in the relevant year and the site was among the initial 690 sites tested for inclusion on the NPL in 1981-82. The controls are listed in the row headings at the bottom of the table. The exact covariates associated with each category are listed in the Data Appendix. In Panel A, the sample size is 48,262 for the "Full NPL Sample" and it is 48,185 for the "1982 HRS Sample" in Panel B. See the text and Data Appendix for further details.

Table 4: Estimates of the First-Stage Relationship and the Association Between the Instrument and 1980 Housing Prices and Rental Rates

	(1)	(2)	(3)	(4)	(5)
A. First Stage Results					
1(NPL Status by 1990)	0.869	0.861	0.855	0.849	0.726
1(1982 HRS Score > 28.5)	(0.025)	(0.026)	(0.028)	(0.030)	(0.057)
1(NPL Status by 2000)	0.833	0.826	0.819	0.807	0.680
1(1982 HRS Score > 28.5)	(0.028)	(0.029)	(0.030)	(0.033)	(0.061)
B. Informal Validity Test					
Ln (1980 Mean Price)					
1(1982 HRS Score > 28.5)	-----	0.028	-0.005	-0.010	0.007
	-----	(0.028)	(0.023)	(0.020)	(0.022)
1980 Prices	A. Yes B. No	A. Yes B. No	A. Yes B. No	A. Yes B. No	A. Yes B. No
1980 Housing Char's	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
Regression Discontinuity Sample	No	No	No	No	Yes

Notes: The table reports results from 14 separate regressions. The dependent variables are underlined in the first column. The table reports the regression coefficient and heteroskedastic consistent standard error (in parentheses) associated with the indicator variable for whether the hazardous waste site received a 1982 HRS score exceeding 28.5. The sample size is 490 in all regressions in columns (1)-(4), which is the number of sites that received 1982 HRS scores and are located in census tracts with non-missing housing price data in 1980, 1990, and 2000. The regression discontinuity sample in column (5) limits the sample to tracts with sites with initial HRS scores between 16.5 and 40.5 and totals 227 census tracts. The controls are listed in the row headings at the bottom of the table. See the text and Data Appendix for further details.

Table 5: Instrumental Variables Estimates of the Effect of NPL Status on House Prices

	(1)	(2)	(3)	(4)	(5)
	A. Ln (Median House Price)				
1990					
1(NPL Status by 1990)	0.065	0.119	0.099	0.039	-0.018
	(0.071)	(0.066)	(0.060)	(0.059)	(0.088)
2000					
1(NPL Status by 2000)	0.067	0.069	0.065	0.062	0.057
	(0.043)	(0.036)	(0.030)	(0.028)	(0.037)
1980 Ln House Price	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
Regression Discontinuity Sample	No	No	No	No	Yes

Notes: The entries report the results from 10 separate regressions, where a census tract is the unit of observation. The 1990 and 2000 values of the ln (median house price) are the dependent variables. The variable of interest is an indicator for NPL status and this variable is instrumented with an indicator for whether the tract had a hazardous waste site with a 1982 HRS score exceeding 28.5. The entries are the regression coefficient and heteroskedastic consistent standard errors (in parentheses) associated with the NPL indicator. The sample is limited to the 490 census tracts with a hazardous waste site that received a 1982 HRS score and non-missing housing price data in 1980, 1990, and 2000. There are 227 observations in the regression discontinuity sample.

Table 6: Instrumental Variables Estimates of the Effect of NPL Status on Rental Rates

	(1)	(2)	(3)	(4)	(5)
	A. Ln (Median Rental Rate)				
1990					
1(NPL Status by 1990)	0.056	0.026	0.021	0.002	-0.059
	(0.047)	(0.043)	(0.043)	(0.048)	(0.082)
2000					
1(NPL Status by 2000)	0.163	0.104	0.105	0.058	-0.028
	(0.037)	(0.034)	(0.028)	(0.027)	(0.044)
1980 Ln Median Rental Rate	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
Regression Discontinuity Sample	No	No	No	No	Yes

Notes: The entries report the results from 10 separate regressions, where a census tract is the unit of observation. The 1990 and 2000 values of the ln (median rental rate) are the dependent variables. The variable of interest is an indicator for NPL status and this variable is instrumented with an indicator for whether the tract had a hazardous waste site with a 1982 HRS score exceeding 28.5. The entries are the regression coefficient sand heteroskedastic consistent standard errors (in parentheses) associated with the NPL indicator. The sample is limited to the 481 census tracts with a hazardous waste site that received a 1982 HRS score and non-missing housing price data in 1980, 1990, and 2000. There are 226 observations in the regression discontinuity sample.

Table 7: Two-Stage Least Squares Estimates of Stages of Superfund Clean-ups on House Prices

	(1)	(2)	(3)	(4)	(5)
Ln (1990 Median House Price)					
1(NPL Only)	0.111	0.117	0.086	0.024	-0.053
[96 Sites, Mean HRS = 41.0]	(0.088)	(0.081)	(0.076)	(0.071)	(0.106)
1(ROD & Incomplete Remediation)	0.034	0.100	0.099	0.023	-0.027
[212 Sites, Mean HRS = 44.5]	(0.072)	(0.067)	(0.063)	(0.059)	(0.091)
1(Const Complete or NPL Deletion)	0.128	0.110	0.050	0.097	0.130
[16 Sites, Mean HRS = 35.3]	(0.208)	(0.172)	(0.172)	(0.165)	(0.167)
P-Value from F-Test of Equality	0.55	0.78	0.94	0.89	0.51
Ln (2000 Median House Price)					
1(NPL Only)	0.206	0.104	0.015	0.012	-0.104
[15 Sites, Mean HRS = 36.2]	(0.156)	(0.112)	(0.082)	(0.059)	(0.078)
1(ROD & Incomplete Remediation)	0.109	0.079	0.070	0.022	0.004
[117 Sites, Mean HRS = 44.1]	(0.046)	(0.042)	(0.035)	(0.031)	(0.049)
1(Const Complete or NPL Deletion)	0.042	0.058	0.062	0.078	0.068
[198 Sites, Mean HRS = 42.1]	(0.043)	(0.035)	(0.032)	(0.031)	(0.040)
P-Value from F-Test of Equality	0.08	0.78	0.78	0.12	0.05
1980 Prices/Rental Rate	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
Regression Discontinuity Sample	No	No	No	No	Yes

Notes: See the Notes to Table 5. Here, the indicator variable for NPL status has been replaced by three independent indicator variables. They are equal to 1 for sites that by 1990 (2000) were placed on the NPL but no ROD had been issued, issued a ROD but remediation was incomplete, and "construction complete" or deleted from the NPL, respectively. The instruments are the interactions of the indicator for a HRS score above 28.5 and these three independent indicators. The table also reports the p-value associated with a F-test that the three parameters are equal.

Table 8: Instrumental Variables Estimates of NPL Status on House Prices in Neighboring Census Tracts, 1990 and 2000

	(1)	(2)	(3)	(4)	(5)
A. Ln (Median House Price) Adjacent Tracts					
1990					
1(Ever NPL Status by 1990)	0.120	0.088	0.050	0.074	0.029
	(0.058)	(0.046)	(0.039)	(0.043)	(0.075)
2000					
1(Ever NPL Status by 2000)	0.104	0.059	0.041	0.058	0.083
	(0.048)	(0.036)	(0.028)	(0.032)	(0.065)
B. Ln (Median House Price) 1 Mile Rule					
1990					
1(Ever NPL Status by 1990)	0.050	0.041	0.009	0.027	0.017
	(0.055)	(0.044)	(0.039)	(0.043)	(0.067)
2000					
1(Ever NPL Status by 2000)	0.039	0.010	0.009	0.004	0.036
	(0.043)	(0.034)	(0.030)	(0.034)	(0.049)
C. Ln (Median House Price) 2 Mile Rule					
1990					
1(Ever NPL Status by 1990)	0.077	0.035	0.034	0.011	-0.023
	(0.046)	(0.037)	(0.032)	(0.024)	(0.043)
2000					
1(Ever NPL Status by 2000)	0.057	0.006	0.018	0.018	0.006
	(0.033)	(0.029)	(0.025)	(0.021)	(0.036)
1980 Prices/Rental Rate	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
Reg Discontinuity Sample	No	No	No	No	Yes

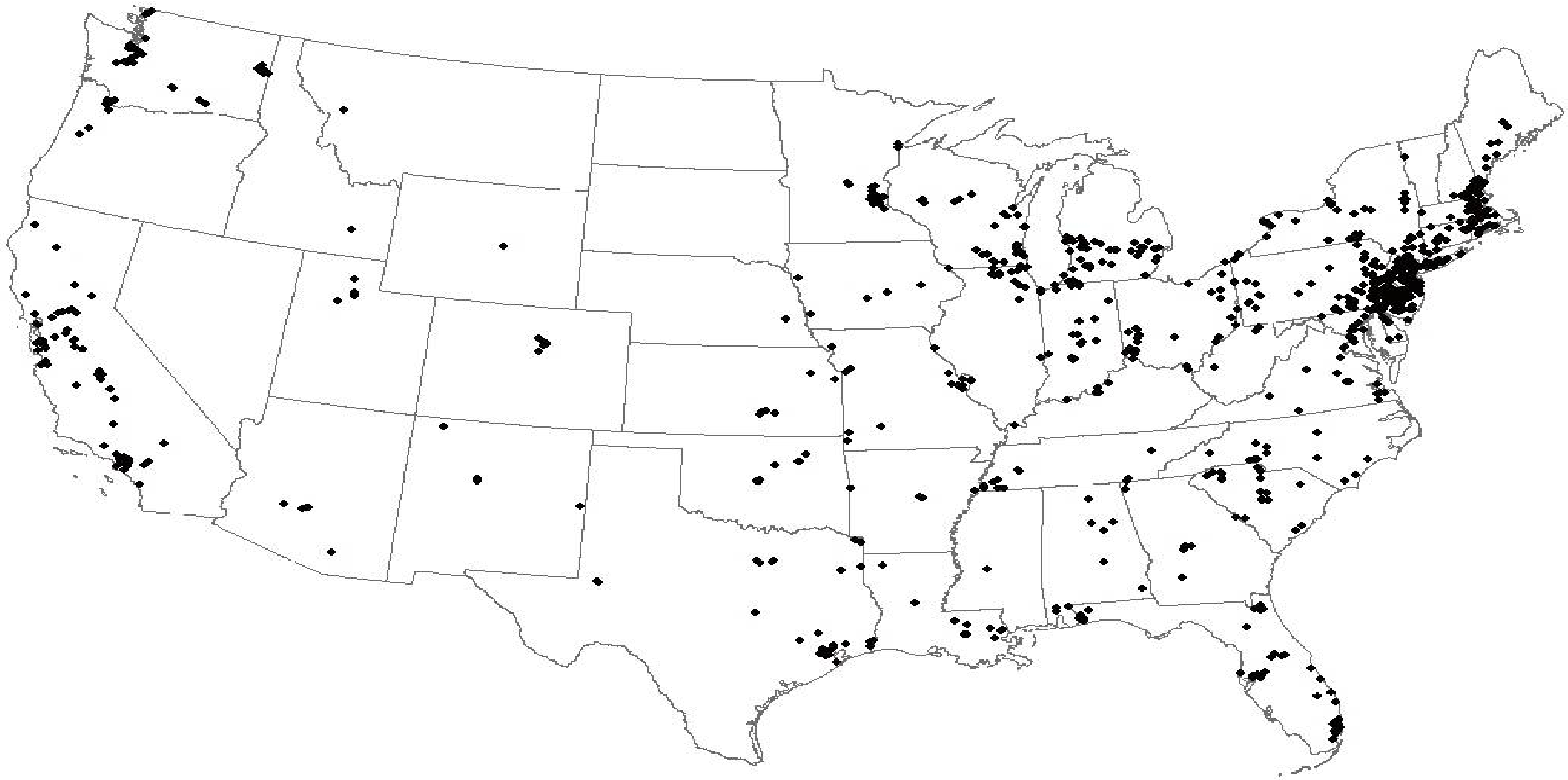
Notes: See the notes to Table 5. Here, the dependent variable and all controls are calculated as the weighted average across the (census tracts that share a boundary with a census tract that contains a hazardous waste site with a 1982 HRS score, where the weight is tract population. The variable of interest remains the NPL status of the hazardous waste site in 1990 (2000). The sample is limited to the neighbors of the 490 census tracts with a hazardous waste site that received a 1982 HRS score and non-missing housing price data in 1980, 1990, and 2000. A neighbor is defined as a census tract that shares a border in panel A. In panels B and C, neighbors are defined to include all populations with 1 and 2 miles, respectively around the borders of the base census tract. The sample sizes are 407 and 189 (regression discontinuity sample), 419 and 193, and 490 and 227 in panels A, B, and C, respectively.

Table 9: Instrumental Variables Estimates of 2000 NPL Status on Population and Housing Stock

	(1)	(2)	(3)	(4)	(5)
A. Housing Units and Population Outcomes					
Total Housing Units					
1(Ever NPL as of 2000)	267	152	130	131	46
	(66)	(61)	(62)	(69)	(109)
Units Built Last 20 Years					
1(Ever NPL as of 2000)	181	118	924	106	56
	(61)	(56)	(57)	(63)	(93)
Population					
1(Ever NPL as of 2000)	689	349	311	329	333
	(180)	(166)	(165)	(180)	(280)
B. Residents' Wealth Outcomes					
% Public Assistance					
1(Ever NPL as of 2000)	-0.018	-0.015	-0.014	-0.013	-0.003
	(0.006)	(0.005)	(0.005)	(0.005)	(0.007)
% BA or Better					
1(Ever NPL as of 2000)	0.015	0.013	0.017	0.017	0.007
	(0.011)	(0.011)	(0.010)	(0.011)	(0.015)
% High School Dropout					
1(Ever NPL as of 2000)	-0.010	-0.011	-0.012	-0.011	0.006
	(0.009)	(0.009)	(0.008)	(0.008)	(0.012)
C. Environmental Justice Outcomes					
% Black					
1(Ever NPL as of 2000)	-0.022	-0.016	-0.014	-0.007	-0.004
	(0.012)	(0.010)	(0.010)	(0.010)	(0.015)
% Hispanic					
1(Ever NPL as of 2000)	0.000	0.002	0.002	-0.005	0.001
	(0.008)	(0.008)	(0.008)	(0.008)	(0.014)
1980 Dependent Variable	Yes	Yes	Yes	Yes	Yes
1980 Prices	No	Yes	Yes	Yes	Yes
1980 Housing Char’s	No	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes
Reg Discontinuity Sample	No	No	No	No	Yes

Notes: The entries report the results from 40 separate regressions. All outcomes are measured in 2000. See text and Notes to Table 5.

Figure 1: Geographic Distribution of NPL Hazardous Waste Sites in All NPL Sample



Notes: “All NPL” sample is comprised of the 984 NPL sites with nonmissing housing price data in 1980, 1990, and 2000 that were placed on the NPL by January 1, 2000.

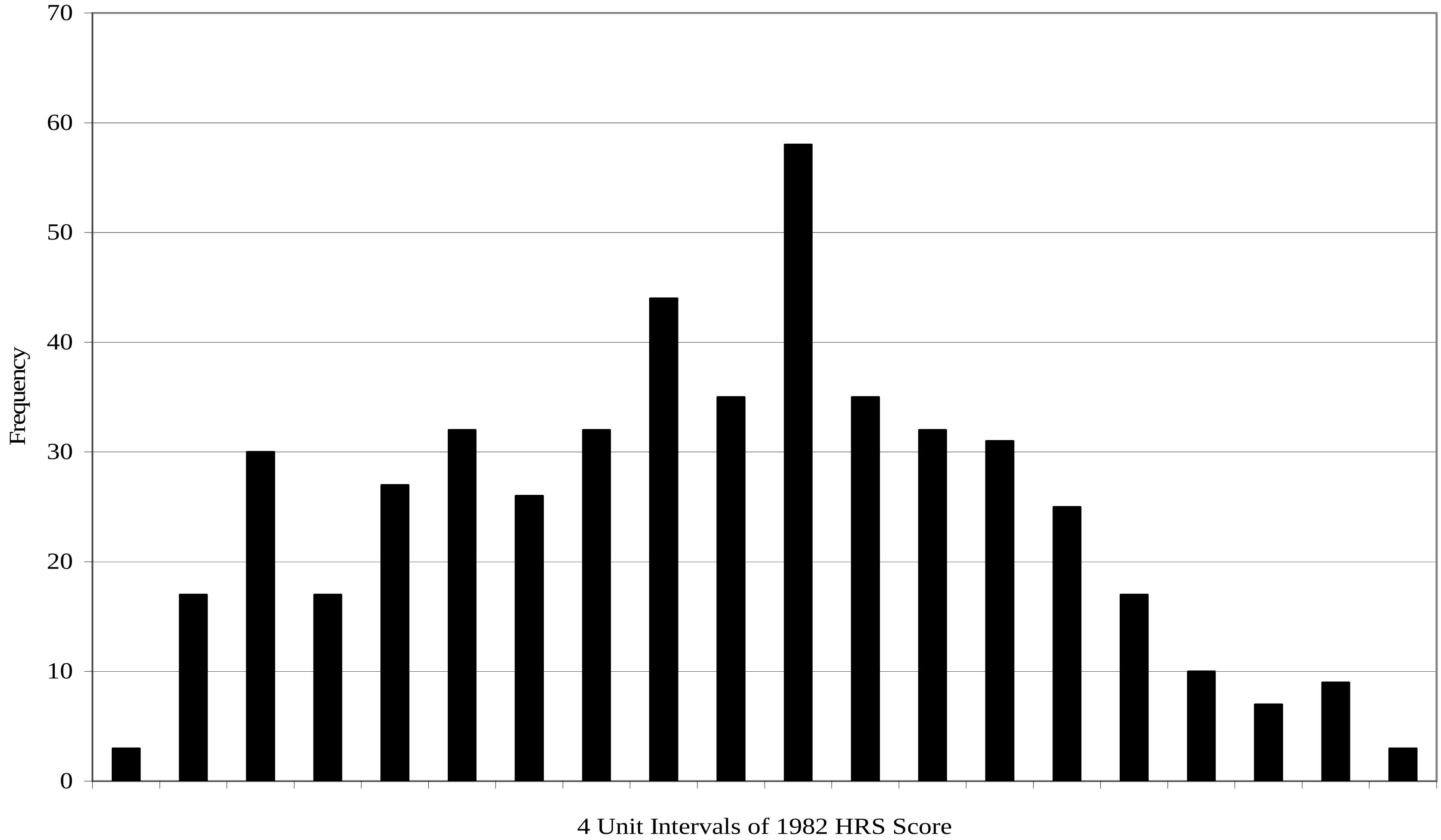
Figure 2: Geographic Distribution of Hazardous Waste Sites in 1982 HRS Sample

A. Sites with 1982 HRS Scores Exceeding 28.5

B. Sites with 1982 HRS Scores Below 28.5

Notes: The "1982 HRS" sample is comprised of the 490 hazardous waste sites with nonmissing housing price data in 1980, 1990, and 2000 that were administered a HRS test by 1982.

Figure 3: Distribution of 1982 HRS Scores



Notes: The figure displays the distribution of 1982 HRS scores among the 490 hazardous waste sites that were tested for placement on the NPL after the passage of the Superfund legislation but before the announcement of the first NPL in 1983. The 184 sites with missing housing data in 1980, 1990, or 2000 are not included in the subsequent analysis and hence are excluded from this figure. The vertical line at 28.5 represents the cut-off that determined eligibility for placement on the NPL.

Figure 4: Estimated Costs of Remediation from Initial Record of Decision, by 4 Unit Intervals of the 1982 HRS Score

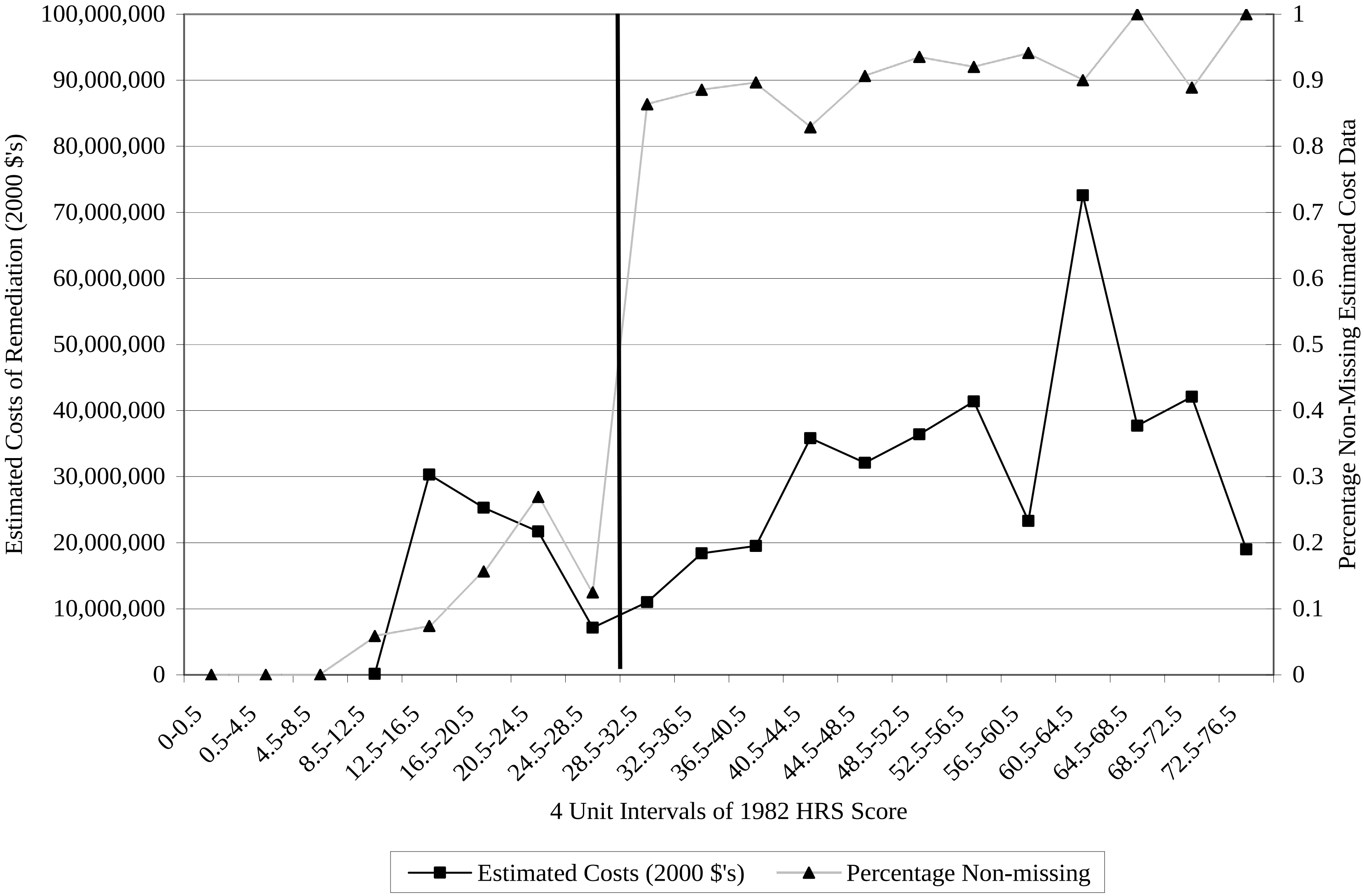


Figure 5: Probability of Placement on the NPL by 1990 and 2000, by 4 Unit Intervals of the 1982 HRS Score

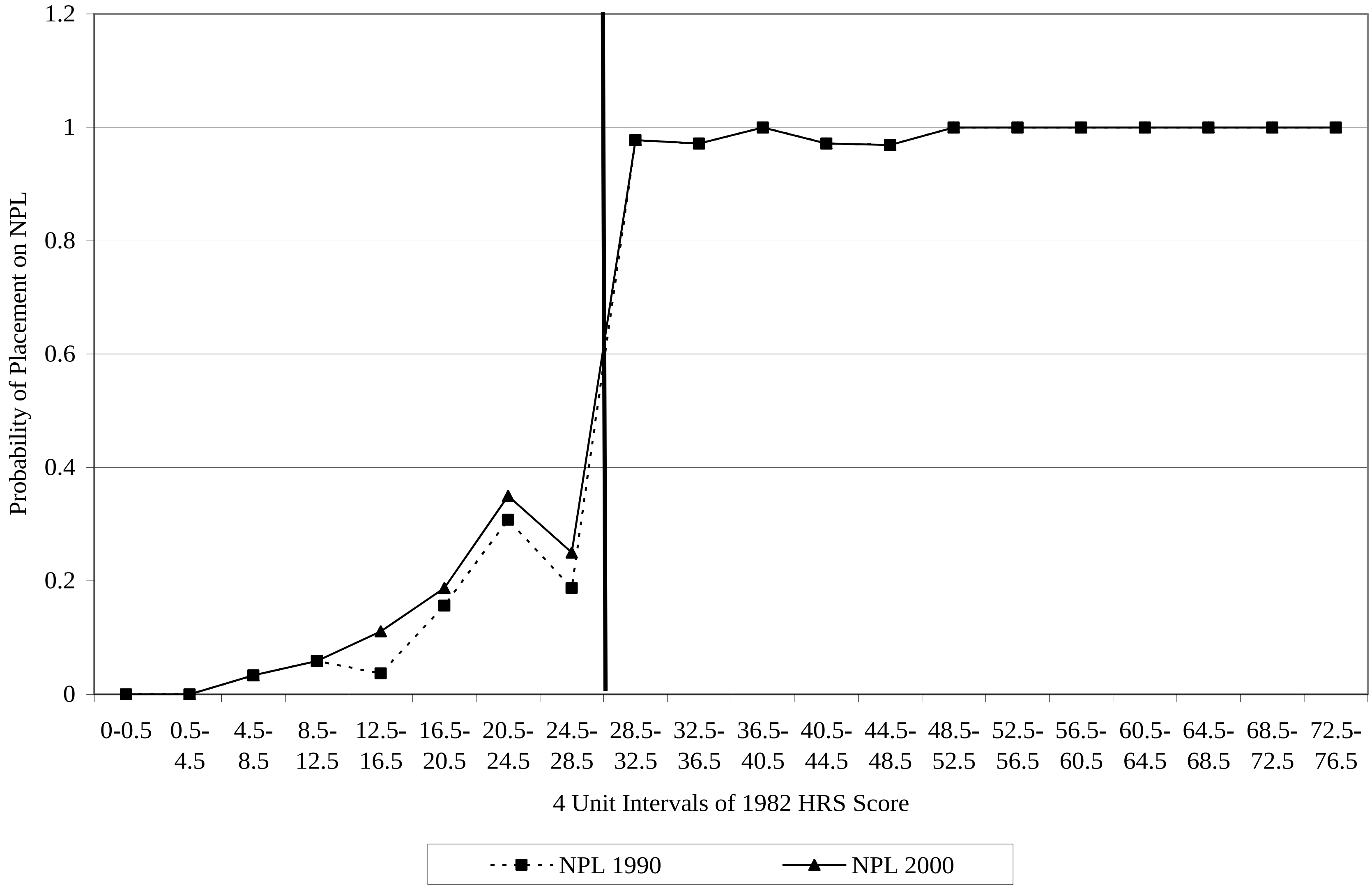


Figure 6: 1980 Residual House Prices After Adjustment for Column 4 Covariates by 4 Unit Intervals of 1982 HRS Score

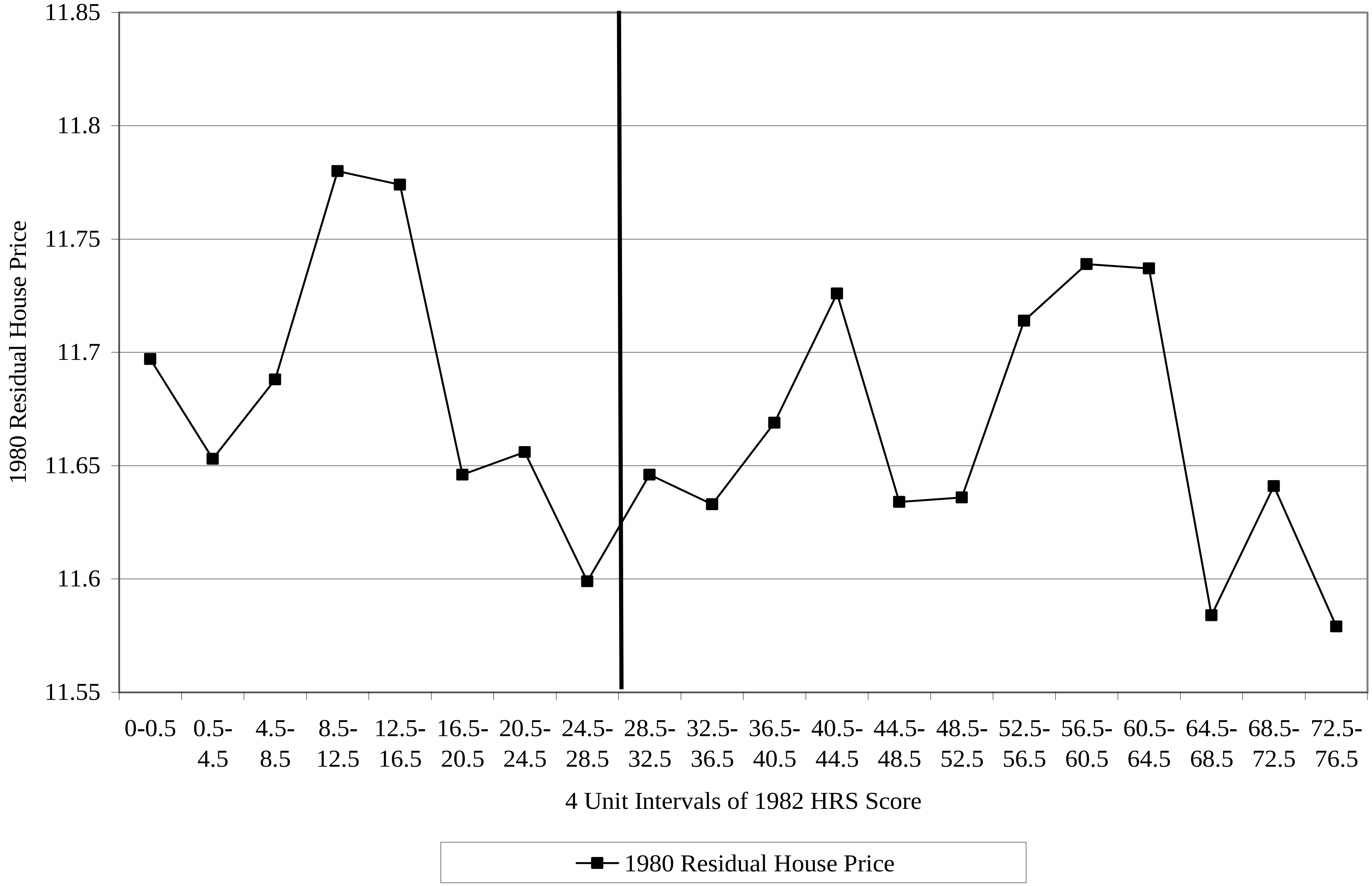


Figure 7: 1990 Residual House Prices After Adjustment for Column 4 Covariates by 4 Unit Intervals of 1982 HRS Score

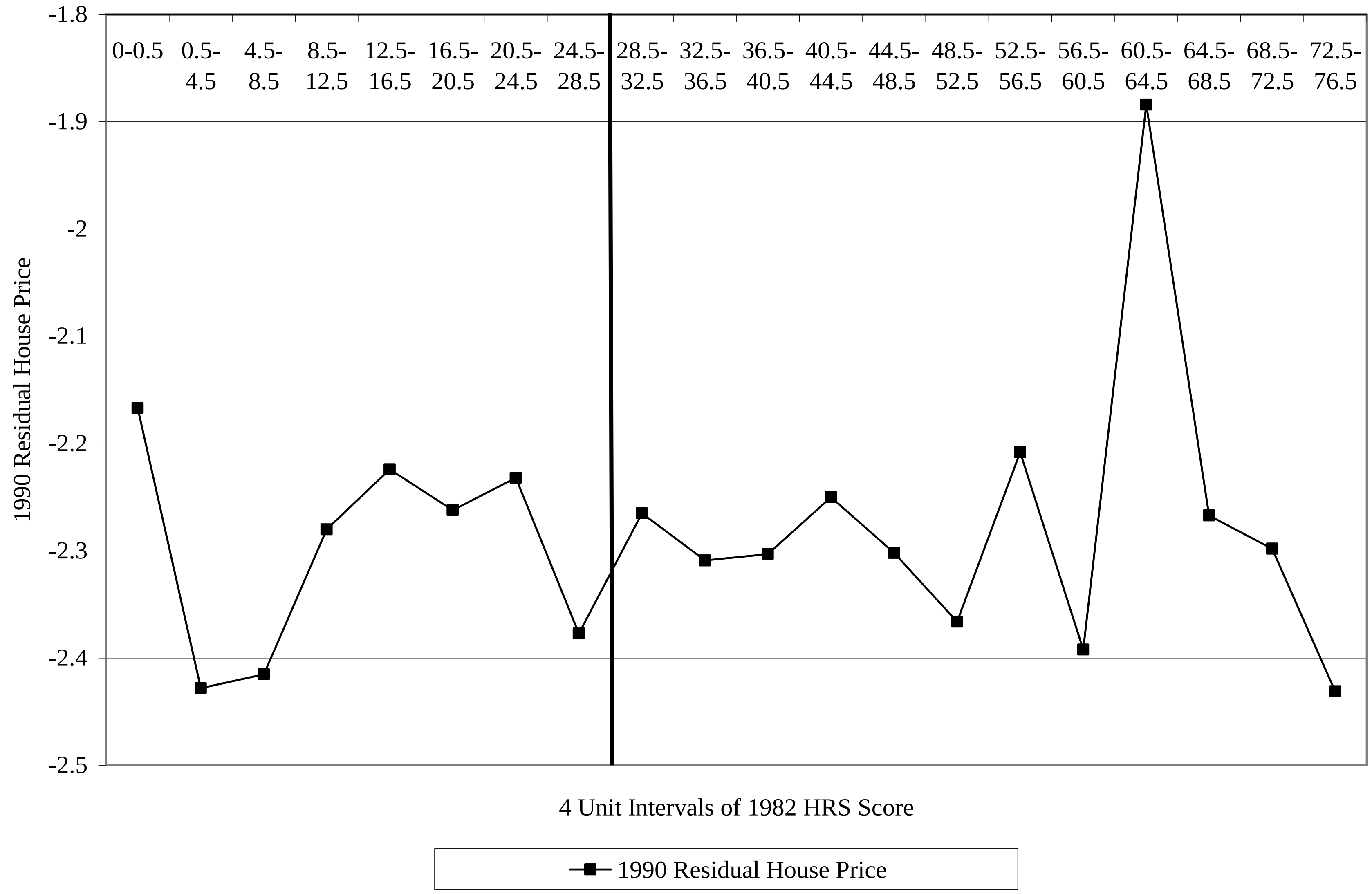


Figure 8: 2000 Residual House Prices After Adjustment for Column 4 Covariates by 4 Unit Intervals of 1982 HRS Score