

PRELIMINARY AND INCOMPLETE
COMMENTS WELCOME

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

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July 2005

* We thank Daron Acemoglu, David Autor, Maureen Cropper, Esther Duflo, Dick Eckhaus, Alex Farrell, Don Fullerton, Ted Gayer, Jon Gruber, Jon Guryan, Joe Gyourko, Matthew Kahn, Jim Poterba, Katherine Probst, Rob Williams and seminar participants at ASSA, BYU, UC-Santa Barbara, CEMFI, HEC Montreal, University of Kentucky, LSE, MIT, NBER, Rand, Resources for the Future, Stanford, Syracuse, Texas, and UCLA for insightful comments. Leila Agha, Brian Goodness, Rose Kontak, William Li, and Jonathan Ursprung provided outstanding research assistance. We especially thank Katherine Probst for generously sharing data on the costs of Superfund clean-ups. Funding from the Center for Integrating Statistical and Environmental Science at the University of Chicago and the Center for Energy and Environmental Policy Research at MIT is gratefully acknowledged. Although the research described herein has been funded wholly or in part by the United States Environmental Protection Agency, through STAR Cooperative Agreement #R-82940201-0 to the University of Chicago, it has not been subjected to the Agency's required peer and policy review and does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

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Abstract

This paper use the housing market to estimate individuals' valuations of clean local environments. Specifically, it uses a newly collected data file to estimate the capitalization into local housing prices of the announcement that a hazardous waste site will be cleaned-up as part of the Superfund program. Under this 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. We focus on the 400 sites placed on the initial Superfund list in 1982, where knowledge of the selection rule, which is a nonlinear function of a continuous measure of risk, allows for the implementation of a quasi-experimental evaluation strategy.

The quasi-experimental estimates suggest that the presence of a Superfund site is associated with economically small and statistically insignificant gains in residential property values, whether this is measured in 1990 or 2000. Further, we fail to detect much evidence of sorting in response to the clean-ups. The quasi-experimental housing price results contrast sharply with estimates from a conventional approach of linear adjustment that finds a positive effect on local housing prices. Overall, the preferred quasi-experimental estimates suggest that the benefits of Superfund clean-ups as measured through the housing market are substantially lower than \$40 million, which is our best estimate of the mean costs of a Superfund clean-up.

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Introduction

The estimation of individuals' valuations of environmental amenities with revealed preference methods has been an active area of research for more than three decades. Numerous theoretical models have been developed that outline methods to recover economically well defined measures of willingness to pay from a variety of settings, including housing markets, recreational choices, health outcomes, and the consumption of goods designed to protect individuals against adverse environmentally-induced health outcomes (for reviews see Freeman 2003; Champ, Boyle, and Brown 2003). However, the application of these approaches is often accompanied by seemingly valid concerns about misspecification that undermine the credibility of any findings.¹ Consequently, many are skeptical that markets can be used to determine individuals' valuation of environmental amenities.

Hazardous waste sites are an environmental disamenity that provokes much public concern. The 1980 Comprehensive Environmental Response, Compensation, and Liability Act, which became known as Superfund, was intended to address these concerns. It gave 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. 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, approximately \$30 billion (2000\$) has been spent on clean-ups and remediation efforts are incomplete at roughly half of the sites. Despite these expenditures, there has not been a systematic accounting of the benefits of Superfund clean-ups of hazardous waste sites and this has made it a very controversial program.²

This study uses the hedonic method to empirically estimate individuals' valuations of the remediation of hazardous waste sites from the residential housing market. The results can also be used to

¹ The increasing reliance on stated preference techniques to value environmental amenities is surely related to dissatisfaction with the performance of revealed preference techniques. See Hanemann (1994) and Diamond and Hausman (1994) for discussions of stated preference techniques.

² 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."

estimate the benefits of the Superfund program. The appeal of the housing market is that if it is operating correctly, prices will capture the health and aesthetic benefits of clean-ups.

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. To solve this problem, we implement a quasi-experiment based on knowledge of the assignment rule that the EPA used to develop the first NPL.

Nearly 15,000 sites were referred to the EPA as potential NPL sites in 1980-1, but the EPA's budget could only accommodate 400 clean-ups. Consequently, they initially winnowed the list to the 690 worst sites and then developed the Hazardous Ranking System (HRS), which assigns each site a score from 0 to 100, to rank these sites on their risk. The EPA placed the 400 sites with HRS scores exceeding 28.5 on the initial NPL in 1983. These sites then became eligible for Superfund remedial clean-ups.

We compare 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. We also implement a quasi-experimental regression discontinuity design (Cook and Campbell 1979) to focus the comparisons in the "neighborhood" of the cut-off.

The quasi-experimental estimates suggest that the presence of a Superfund site is associated with economically small and statistically insignificant gains in residential property values, whether this is measured in 1990 or 2000. The validity of these findings is supported by the finding that observable determinants of housing price appreciation are well balanced among census tracts with HRS scores above and below 28.5, especially near the cut-off. Thus, these findings suggest that the benefits of Superfund clean-ups as measured through the housing market are substantially lower than \$40 million, which is our best estimate of the mean costs of a Superfund clean-up.

These estimates of marginal willingness to pay for remediation contrast sharply with those obtained from a more conventional comparison of census tracts with NPL sites to all other tracts in the US. The conventional approach implies property value gains approximately equal to the costs of the clean-ups. However, the determinants of changes in housing prices differ dramatically between census

tracts with NPL sites and the remainder of the country. This finding underscores the importance of the availability of our research design.

We also examine whether the clean-ups lead to changes in the population and demographic characteristics of the tracts with one of the NPL sites. The quasi-experimental estimates fail to find significant evidence of sorting in response to the clean-up. For example, the percentage of households that receives public assistance, the percentage black, and the percentage under the age of 6 all appear to be unchanged.

In addition to the availability of the quasi-experiment, our approach differs from previous research on the benefits of the Superfund program in two important ways. First, the analysis is conducted with a data file on all Superfund hazardous waste sites, the sites that narrowly missed placement on the initial NPL, and census-tract level housing prices for 1980, 1990, and 2000. The data file also contains a wealth of information on the hazardous waste sites, including the census tract they are located in, HRS scores, the expected and actual costs (where relevant), and the size in acres. This is the most comprehensive data file ever compiled by the EPA or other researchers on the Superfund program and its effects. The result is that this study is a substantial departure from previous Superfund hedonic studies that examines a single site or handful of sites (Smith and Michael 1990; Kohlhase 1991; Kiel 1995; Gayer Hamilton, and Viscusi 2000 and 2002).

Second, we assume that individuals transmit their valuations of the reduction in health risks and aesthetic improvements of future clean-ups through the housing market. This assumption frees us from a reliance on the notoriously poor estimates of risk to human health associated with the thousands of chemicals present at these sites. Consequently, all welfare calculations are derived from consumers' revealed preferences and not from EPA laboratories and assumptions about the appropriate value of a statistical life.³

³ 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 current knowledge is insufficient to successfully implement the health effects approach 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.⁴

Third, even for chemicals where reliable dose-response evidence is available, 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 residential 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, each of which involves substantial uncertainty. In light of these scientific, empirical, and data quality concerns outlined here, we feel it 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 in Practice

⁴ 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) and Freeman (1974) were 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, $Q = (q_1, q_2, \dots, q_n)$. 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:

$$(1) \quad P_i = P(q_1, q_2, \dots, q_n).$$

The partial derivative of $P(\bullet)$ 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.⁵ 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.⁶

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

⁵ See Rosen (1974), Freeman (1993), and Palmquist (1991) for details.

⁶ 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.

marginal cost of producing it. Since the HPS reveals the MWTP at a given point, it can be used to infer 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. In principle, the hedonic method can also be used to recover individuals' demand or MWTP functions, which would be of tremendous practical importance because they allow for the calculation of the welfare effects of nonmarginal changes.⁷

The consistent estimation of (1) is the foundation for accurate welfare calculations of both marginal and non-marginal changes, however this may be difficult since it is likely that there are unobserved factors that covary with both environmental amenities and housing prices.⁸ 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 other settings, including the relationships between land prices and school quality, total suspended particulates air pollution, and climate variables (Black 1999; Chay and Greenstone 2005; Deschenes and Greenstone 2004).⁹

The consequences of the misspecification of equation (1) 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].

⁷ 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.

⁸ 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.

⁹ 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).

In the intervening years, this problem of misspecification has received little attention from empirical researchers, even though Rosen himself recognized it.¹⁰ One of this paper's aims is to demonstrate that it may be possible to obtain credible hedonic estimates with a quasi-experimental approach.

Before proceeding it is worth emphasizing that although it is tempting to implement the full blown hedonic method to obtain estimates of marginal willingness to pay functions, our focus is limited to the successful estimation of equation (1). Our data source on housing prices is the decennial census files on census tract-level housing prices. In our view, the inability to link individuals across censuses and the long period between observations makes it invalid to interpret changes in house prices across censuses as measures of a fixed set of individuals' willingness to pay. However, these data are fine for the estimation of the market locus as specified in (1).

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

¹⁰ 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).

¹¹ EPA (2000) claims that 56% of the children born in Love Canal between 1974 and 1978 had birth defects.

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.

The centerpiece of the Superfund program, and this paper's focus, is the long-run remediation of hazardous waste sites.¹² These multi-year remediation efforts aim to reduce permanently the dangers due to hazardous substances that are serious, but not imminently life-threatening. As of 2000, roughly 1,500 sites have 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

As of 1996, more than 40,000 hazardous waste sites had been referred to the EPA for possible inclusion on the NPL. The EPA follows a multi-step process to winnow these sites down to the most dangerous ones. The assessment process includes a determination of which hazardous chemicals are present at the site and the overall prevailing risk level.

The final step of the assessment process is the application of the Hazardous Ranking System (HRS) and this test is reserved for the most dangerous sites. 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.¹³ 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.

¹² The Superfund program also funds immediate removals. These clean-ups are responses to environmental emergencies and are generally short-term actions aimed at diminishing an immediate threat. Examples of such actions including clean up waste spilled from containers and the construction of fences around dangerous sites. These actions are not intended to remediate the underlying environmental problem and account for a small proportion of Superfund activities. Importantly, they are administered at hazardous waste sites that are and are not on the NPL.

¹³ In 1990, the EPA revised the HRS test so that it also considers soil as an additional pathway.

The HRS produces a score for each site that ranges from 0 to 100, with 100 being the highest level of risk. From 1982-1995, the EPA assigned all hazardous waste sites with a HRS score of 28.5 or greater to the NPL.^{14 15} These sites are the only ones that are eligible for Superfund remedial clean-up. The Data Appendix provides further details on the determination of HRS test scores.

C. Clean-Up of NPL Sites

Once a site is placed on the NPL, it generally takes many years until clean-up is complete. The first step toward clean-up for NPL sites is a further study of the extent of the environmental problem 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. In our primary sample, the median time between NPL listing and the release of the ROD is roughly 4 years. The next step is the initiation of clean-up activities and 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. On average, it takes about one more year for the EPA to officially delete the site from the NPL.

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

This paper’s goal is to obtain 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. The empirical difficulty is that NPL sites are the most polluted in the US, so the evolution of housing prices

¹⁴ 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.

¹⁵ 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.

near these sites may not be comparable to the remainder of the US, even conditional on observable covariates. To avoid confounding the effects of the clean-ups with unobserved variables, 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.

A feature of the process of the assignment of sites to the initial NPL that has not been noted previously by researchers may provide a credible solution to the likely omitted variables problem. In the first year 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. The Superfund legislation directed the EPA to develop a NPL of "at least" 400 sites (Section 105(8)(B) of CERCLA) and budgetary considerations caused the EPA to cut the 690 final sites down to 400.

The EPA developed the HRS to determine scientifically the 400 sites most worthy of clean-ups. Due to pressure to initiate the clean-ups quickly, the EPA developed the HRS in about a year. The HRS test was applied to the 690 worst sites and their scores were ordered from highest to lowest. A score of 28.5 divided number 400 from number 401 and the initial NPL published in September 1983 was limited to sites with HRS scores exceeding 28.5.¹⁶

The central role of the HRS score 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, it is unlikely that sites' HRS scores were manipulated to affect their placement on the NPL, because the 28.5 threshold was established after the testing of the 690 sites was completed. This means that the HRS scores reflected the EPA's assessment of the human health and environmental risks associated with the site and were not based on the expected costs or benefits of clean-up.

Second, the HRS scores were noisy measures of risk so it is possible that true risks were similar above and below the threshold. This noisiness was a consequence of the scientific uncertainty about the

¹⁶ 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.

health consequences of many of the tens of thousands of chemicals present at these sites.¹⁷ 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 the “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. XX) and that a more informative test would require “greater time and funds” (EPA 1982).¹⁸ Together, the HRS scores’ noisiness and the budgetary motivation for the 28.5 cutoff are attractive features 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 features of the analysis. 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.¹⁹ 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

¹⁷ 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).

¹⁸ 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.

¹⁹ 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.

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 sites 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 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.

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 and 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 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.²⁰

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 $1(\cdot)$ 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.²¹ 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.

²⁰ 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.

²¹ 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.

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:

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

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 $t_{\text{Superfund}}$ 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 $t_{\text{WTP for Superfund}}$ 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:

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

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 $[P^{HRS > 28.5} | H = H_3]$ with data from that census year. It is important to note that $t_{\text{Clean-Up}}$ 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

To implement the analysis, we constructed the most comprehensive data file ever compiled on the Superfund program. The data file contains detailed information on all sites ever placed on the NPL, as well as the hazardous waste sites with initial HRS scores below 28.5. We also compiled housing price and demographic information for the areas surrounding these sites.

The housing price housing characteristic and demographic data comes from Geolytics's *Neighborhood Change Database*, which includes information from the 1980, 1990, and 2000 Censuses. It provides a panel data set of census tracts based on 2000 census tract boundaries, which are drawn so that they include approximately 4,000 people in 2000.²² We restrict the analysis to the 48,556 out of the 65,443 2000 census tracts that have non-missing housing price data in these years.

We spent considerable effort collecting precise location data (e.g., longitude and latitude) for each of the NPL sites and hazardous waste sites with initial HRS scores below 28.5. This information was used to place these sites in unique census tracts. We also used GIS software to identify the census tracts that neighbor the tracts with the sites. We define neighbors in two ways: tracts that share a border and tracts that fall within distance rings (e.g., 1 mile) of the site. The Data Appendix provides further details on these issues.

A key feature of the analysis is the initial HRS scores for the 690 hazardous waste sites considered for placement on the initial NPL. 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 our estimates of the 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 sites. The Data Appendix provides explanations of how these variables were collected and defined, as well as details on the data sources.

B. Summary Statistics

²² Census tracts are the smallest geographic unit that can be matched across the 1980, 1990, and 2000 Censuses. See the Data Appendix for a description of how 1980 and 1990 census tracts were adjusted to fit 2000 census tract boundaries.

The analysis is conducted with two data samples. We refer to the first as the “All NPL Sample,” and it includes the 1,398 hazardous waste sites in the 50 US states and the District of Columbia placed on the NPL by January 1, 2000. The second is labeled the “1982 HRS Sample” and it is comprised of the hazardous waste sites tested for inclusion on the initial NPL, regardless of their eventual placement on the NPL.

Table 1 presents some summary statistics on the hazardous waste sites in these 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, there are 985 sites or nearly 70% of the sites 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 487 sites that we were able to place in a census tract with complete housing price data. Column (3) reports on the remaining 188 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 442 of the 675 sites in the 1982 HRS sample 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 rescored occurred in the 1986-1990 period. Panel B provides mean HRS scores, conditioned on scores above and below 28.5. Notably, 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 modest size of most sites suggests that any expected effects on property values may be confined to relatively small geographic areas.²³ In the subsequent analysis, we will separately test for effects on

²³ 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.

property values in the census tracts that contain the sites and tracts that neighbor these tracts.

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 482, 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 (2000 \$'s) of the clean-up before any remedial activities have begun.²⁴ 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 753 of the 984 NPL sites. The mean and median expected costs of clean-up are \$28.3 million and \$11.1 million. 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.²⁵ 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%

²⁴ All monetary figures are reported in 2000 \$'s, unless otherwise noted.

²⁵ We measure actual cost as the sum of government outlays and estimates of the costs of the remediation that were paid for by non-governmental responsible parties. The actual outlays by these private groups is unavailable. See the Data Appendix for further details.

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 the two samples. Figure 1 displays the geographic distribution of the 985 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 487 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 that we exploit in the subsequent analysis.

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:

$$(7) \quad y_{c90} = \theta 1(\text{NPL}_{c90}) + X_{c80} \beta + \varepsilon_{c90}, \quad \varepsilon_{c90} = \alpha_c + u_{c90}$$

$$(8) \quad 1(\text{NPL}_{c90}) = X_{c80}' \Pi + \eta_{c90}, \quad \eta_{c90} = \lambda_c + v_{c90},$$

where y_{c90} is the log of the median property value in census tract c in 1990. The indicator variable $1(\text{NPL}_{c90})$ 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 as 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 (α_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.A Quasi-Experimental Approach 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 487 sites that were considered for placement on the initial NPL and have complete housing price data. 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 is more likely to produce consistent estimates. Second, we use an instrumental variables strategy to account for the possibility of endogenous rescoreing of sites.

More formally, we replace equation (8) with:

$$(9) \quad 1(\text{NPL}_{c90}) = X_{c80}'\Pi + \delta 1(\text{HRS}_{c82} > 28.5) + \eta_{c90}, \quad \eta_{c90} = \lambda_c + v_{c90},$$

where $1(\text{HRS}_{c82} > 28.5)$ 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 portion of the nonlinear function of the 1982 HRS score that is not explained by X_{c80} . In the simplest case, the IV estimator is consistent if $E[1(\text{HRS}_{c82} > 28.5) \varepsilon_{c90}] = 0$.

We implement the IV estimator in two ways. First, we fit the IV estimator on the data from the 487 sites with nonmissing housing price data to obtain θ_{IV} . We also calculate IV estimates another way that allows for the possibility that $E[1(\text{HRS}_{c82} > 28.5) \varepsilon_{c90}] \neq 0$ 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 $[1(\text{HRS}_{c82} > 28.5) \varepsilon_{c90}] = 0$ 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 $1(\text{HRS}_{c82} > 28.5)$ 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 $1(\text{HRS}_{c82} > 28.5)$ with potential 1980 determinants of housing prices. Columns (1) and (2) report the means of the variables listed in the row headings in the 181 and 306 census tracts with hazardous waste sites with 1982 HRS scores below and above the 28.5 threshold, 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 more than 30% higher in the rest of the US. Among the potential determinants of housing prices, the hypothesis of equal means can be rejected at the 5% level for 9 of the 11 demographic and economic variables and 4 of 11 of the housing characteristics. The tracts with these hazardous waste sites are more rural (see population density) and poorer. One variable that seems to capture this is that the fraction of the housing stock that is comprised of mobile homes is more than 60% greater (0.0813 versus 0.0496) in tracts with these sites. Additionally, the fraction of Blacks and Hispanics is greater in tracts without NPL sites, which undermines “environmental justice” claims in this context. Overall, it is evident the presence of a site with a HRS score exceeding 28.5 is correlated with many determinants of housing prices.²⁶ It may be reasonable to assume that the estimation of equation (7) will produce biased estimates of the effect of NPL status.

²⁶ The results are similar when the tracts with NPL sites in the All NPL Sample are compared to the remainder of the

Column (7) compares the below and above 28.5 samples and here the differences in the potential determinants of housing prices are smaller than in the previous comparison. For example, the population density and percentage of mobile homes is balanced across these two groups of census tracts. One important difference that remains is that the mean housing price in 1980 is roughly 16% higher in tracts with HRS scores above 28.5. Overall, the entries suggest that the above and below 28.5 comparison reduces confounding of NPL status with other determinants of the growth of housing prices.

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 at the 1% level for a single one of the potential determinants of housing prices. This finding means that it may be reasonable to put the most stock on comparisons near the regulatory threshold.

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 3 and 4) 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 from the All NPL Sample

Table 3 reports the regression results from fitting 4 versions of equation (7) for 1990 and 2000 housing prices. The sample size is 48,262 in all regressions. 47,508 (47,272) of these observations are from the census tracts without a NPL hazardous waste site in 1990 (2000). In Panel A, the remaining 754 (985) observations in 1990 (2000) are from census tracts that contain a hazardous waste site that had ever been on the NPL at the time of the housing price observation. In Panel B, these observations are replaced with averages across all census tracts with complete housing price data that share a border with the tract containing the site. The intent in this panel is to test whether the NPL designation affects housing prices outside of the site's tract.

US.

The entries report the coefficient and heteroskedastic-consistent standard error on the NPL indicator. All specifications control for the ln of the mean housing price in 1980, so the reported parameter should be interpreted as the growth in housing prices in tracts with a NPL site (or its neighbors), relative to other tracts. 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 8.9% 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 estimate is probably the column (4) one of 8.9% that is adjusted for all unobserved state-level determinants of price growth.

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 3.8% to 6.8% 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 $\frac{1}{2}$ 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.

Panel B explores the growth of housing prices in the census tracts that are adjacent to the tracts with the sites that contain the NPL site. 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 column (4) specification indicates 4.5% and 7.2% gains in 1990 and 2000, respectively.

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 the NPL designation of a hazardous waste site is associated with substantial gains in housing prices in the

tract that contains the site and neighboring tracts. 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 1980 mean of aggregate property values in tracts with NPL sites is roughly \$77 million and the analogous figure in adjacent tracts is about \$600 million. Thus, the column (4) estimates suggest that by 2000 overall mean property values were approximately \$48 million higher in the areas surrounding the sites due to the Superfund program. The confounding of NPL status in Table 2 is a cause for concern and we now turn to the preferred quasi-experimental estimates to probe 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 bivariate relation between the probability of 1990 (Panel A) and 2000 (Panel B) NPL status and the 1982 HRS score among the 487 sites in the 1982 HRS sample. The plots are done separately for sites above and below the 28.5 threshold and come from the estimation of nonparametric regressions that use Cleveland’s (1979) tricube weighting function and a bandwidth of 0.5.²⁷ Thus, they represent a moving average of the probability of NPL status across 1982 HRS scores.

The figures present 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 rescaling) 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 five columns, the sample is comprised of the 487 census tracts in the 1982 HRS Sample. The controls in the first four columns are identical to those in the four specifications in Table 3. In the fifth column, the 1982 HRS

²⁷ The smoothed scatterplots are qualitatively similar without the weighting function (i.e., equal weighting) and alternative bandwidths.

score and its square are added to the column 4 specification so that the estimates are adjusted for a smooth function of the “running” variable. Here, the identification comes from the nonlinear function that determines NPL status. In the column (6), the sample is restricted to the regression discontinuity sample comprised of the 227 sites with HRS scores between 16.5 and 40.5 and 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 61% and 86%, 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 $1(\text{HRS}_{c82} > 28.5)$ from five regressions. In the first and second rows of the Panel, the dependent variables are the ln of 1980 mean housing prices in the tract with the hazardous waste site and the ln of the mean of the mean house price across the census tracts that share a border with the tract containing the NPL site, respectively. 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 would undermine the validity of our approach.

After adjustment for the housing characteristics, the point estimate on the above 28.5 indicator is small both economically and statistically. This finding holds in the 1982 HRS and regression discontinuity samples.

Figure 6 allows for a graphical investigation of this test. It plots the results from nonparametric regressions between 1980 residual housing prices after adjustment for the column (4) covariates (except the indicator for a HRS score above 28.5) and the 1982 HRS scores. These plots are done separately for sites above and below the threshold. In Panel A the All NPL sample is used while in Panel B the regression discontinuity sample is employed.

In both figures, there is little evidence of a relationship between the 1982 HRS score and 1980 residual housing prices. Importantly, there are only modest differences in residual housing prices just above and below the regulatory threshold. Along with the Tables 2 and 4 findings, these plots appear to support the validity of our quasi-experimental approach that uses comparisons of tract with sites above and below the HRS threshold to infer effect of NPL status on property values.

D. Quasi-Experimental Estimates of NPL Status on Housing Prices

Table 5 presents instrumental variables estimates of the effect of NPL status on housing prices in 1990 and 2000. In Panel A the observations are on the census tracts that contain the 487 hazardous waste sites in the 1982 HRS sample. Recall, these sites were judged to be the most dangerous among the nearly 15,000 initially inspected by the EPA. In Panel B they are the average across the tracts that share a border with the tracts that have the sites within their boundaries. The 6 combinations of samples and control variables are identical to those in Panel A of Table 4.

The Panel A results suggest that a site's placement on the NPL has little impact on the growth of property values in its own census tract, relative to census tracts with sites that narrowly missed placement on the NPL. The 1990 and 2000 point estimates from the own census tract regressions range from -0.6% to 6.6%, but none of these estimates has an associated t-statistic greater than 2. The regression discontinuity specifications in columns (5) and (6) are demanding of the data and this is reflected in the relatively larger standard errors. However, these specifications may be less subject to concerns about omitted variables bias. Consequently, it is notable that they produce the smallest point estimates.

Panel B tests for price effects in the tracts that neighbor the NPL sites. The estimates from the more reliable specifications lie in a tight range of -2% to 2%. Further, the null hypotheses of a zero effect would not be rejected by conventional criteria for any of the 12 estimates.

Figures 7 and 8 provide an opportunity to better understand the source of these regression results. They are constructed identically to Figure 6 and plot the nonparametric regressions of 2000 residual housing prices (after adjustment for the column 4 covariates) against the 1982 HRS Score in the Full 1982 HRS and Regression Discontinuity samples. The figures are for the own and adjacent census tract

housing prices, respectively. They are the graphical version of the reduced form relationship between the instrument and housing price growth.

These graphs reveal that there is little association between the 1982 HRS score and 2000 residual housing prices. A comparison of the plots at the regulatory threshold is of especial interest in light of the large jump in the probability of placement on the NPL there that was documented in Figure 4. In all four of these plots the moving averages from the left and right are virtually equal at the threshold.

Table 6 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 $1(\text{HRS}_{c82} > 28.5)$ variable with the indicators for these three stages of the NPL process.

The purpose of this exercise is to test whether the effect on housing prices varies with the different stages of the remediation process. It also allows us an opportunity to examine whether the zero effect in Table 5 was because remediation efforts were incomplete at substantial fractions of the sites in 1990 and 2000. 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 begin by focusing 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 1.4% to 6.3%. Only one of these would be judged to statistically differ from zero. The “ROD and Incomplete Remediation” category’s point estimates range from positive to negative, but the zero cannot be rejected in the more robust specifications (i.e., columns (4) through (6)) The null that the parameters on the indicators for the three different stages of clean-up

are equal cannot be rejected in any of the specifications. These results are consistent with those in Table 5 that suggested that Superfund clean-ups have little effect on local property values.

Another attractive feature of this table is that it provides an appealing setting to test the popular theory that a site's placement on the NPL leads to price declines. The sites in the "NPL Only" category have been on the NPL for 7 (17) years by 1990 (2000), but the EPA has not issued a ROD. Thus, these sites seem like prime examples of sites where individuals have revised their expectation of the current risk associated with proximity to the site but the clean-up is still far away. The 1990 results are the most useful to explore this question, because 112 sites were in this category in this year. These point estimates fail to provide much evidence in favor of an initial price decline as 4 of the 6 estimates are positive, although none of them have a t-statistic that exceeds one.

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

Table 7 estimates IV models for a series of demographic variables with the same six specifications used in Tables 5 and 6. 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 is a test of whether individuals sort in response to changes in environmental amenities.

The most robust finding is that there appears to be an increase in the total population in tracts with the Superfund sites. However, these estimates would generally be considered statistically insignificant by conventional criteria. The point estimates for the total housing units variable are also positive, but the findings are weaker in the regression discontinuity 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 in the fraction of with a BA or higher, however the larger standard errors in the regression discontinuity approaches precludes definitive conclusions. It appears that the fraction of Blacks or Hispanics did not change in a meaningful way.

VI. Interpretation

To Come.

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.²⁸ Each pathway score is capped at 100.²⁹ 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:

$$(1) \text{ HRS Score} = [(S_{\text{gw}}^2 + S_{\text{sw}}^2 + S_{\text{a}}^2) / 3]^{1/2},$$

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.³⁰ 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).³¹

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.

²⁸ See the EPA's *Hazard Ranking System Guidance Manual* for further details on the determination of the HRS score.

²⁹ 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.

³⁰ See Brody (1998) for a list of EPA studies that have examined this issue.

³¹ 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. Note on Construction Complete Site Data

The Construction Complete variable was created by the EPA to gauge progress on remediating National Priority List sites. The EPA first began using this designation in 1990. However, it is evident from the remedial action site histories and a construction complete datafile we received from the EPA that construction complete definitions were retroactively assigned to pre-1990 sites.

There are 4 sites in our samples which have been deleted but for which no Construction Complete dates are provided. The site ids for these sites are ARD059636456, KSD007241656, MND000686071, WID990829475. These sites were all deleted between 1990 and 2000 and since construction complete is a precursor for deletion we assign each site a 1 for con_comp, the variable that tracks whether the site was construction complete before year 2000. Based on Table 1 summary statistics sites are—on average—listed as Construction Complete approximately 1 year before deletion. We assign proxy Construction Complete dates for these 4 sites that are 1 year before they were deleted. We then use these to assign values to the 1990 and 2000 Construction Complete dummy variables.

V. Notes on No Further Action Rods and Total Rods

A. Number of Operating Units (OUs), Operating Units with Expected Cost Data, and Proportion of Operating Units with Cost Data

Data on the number of operating units at each site and the number with associated expected costs were collected from CERCLIS for each National Priority List site. These variables are used as one measure to determine whether all expected costs have been incurred at each site. Important to note, however, is that there at least 3 reasons why the number of OU's at a site may not correspond to the number of RODs for the site:

1. If remedial action at the site is still in progress and there are OU's that haven't been specifically addressed by a rod. This is the initial reason that the data were collected. We wanted to be sure that we were capturing all expected costs (i.e. from each part of the site).
2. Occasionally a site will be Construction Complete or Deleted without having a specific

ROD for each anticipated OU. The most likely explanation is that remedial action for the other OU's or the removal activity for another OU or for that OU addressed the problem.

3. Sometimes there is more than one ROD for the same OU. This is different than having an amended ROD. For an amended ROD, the old remedial action in the 1st ROD is changed. In the cases where there are 2 RODs for the same OU, there is additional remedial activity on that OU.

B. No Further Action RODs and No Further Action Sites

A list of No Further Action (NFA) RODs by Operating Unit was provided to us by Kate Probst at Resources for the Future. A NFA ROD is a ROD that is developed with the anticipation that an Operating Unit would require remedial action, but where the EPA determined that no remedial action was still needed.

One implication of sites with NFA RODs is the possibility that there is never any remedial action cleanup at some National Priority List sites. This would occur if all of the RODs at a particular site were NFA RODs. In such a case, a site could be deleted from the National Priority List without ever having a remedial cleanup under the Superfund program.

We cross-checked the list of No Further Action RODs provided to us by Resources for the Future with the EPA Cerclis database. The purpose of this was to verify that (1) these RODs were NFA RODs and (2) to determine the total number of RODs at each site. If all of the RODs for a site were NFA RODs then we defined the site as being a 'No Further Action Site'. It is important to note that given considerations (a)-(c) above that the number of RODs at a site may not correspond to the number of operating units. For NFA RODs we are specifically interested in the total number of RODs and not the total number of OU's.

Finally, just because a ROD is a NFA ROD it doesn't imply that there was no cleanup activity at the OU associated with the ROD. Occasionally an operating unit will have more than one ROD. Also, it is often the case that there were separate removal activities or remedial actions carried out under a consent agreement before the ROD was published. In such cases cleanup work was done at the site and more specifically at the part of the site defined under that OU. There were significant costs associated with these activities at many of the sites. Many of the NFA RODs actually detailed costs in the millions and included operating and maintenance activities similar to those of non-NFA RODs.

Whether or not 'No Further Action Sites' would have received the same cleanup considerations as sites that never made it on the NPL is a relevant question for our analysis. If the answer is "No" then these sites may be more similar to the other NPL sites that did have formal remedial action plans. Below are examples from the ROD Abstracts for 3 NFA RODs that highlight this question.

1. For site: San Gabriel Valley (Area 1), CAD980677355

"The selected remedial action for this site is no action, with ground water monitoring. Site investigations have confirmed that contaminants within OU2 currently pose no risk to human health and the environment. The estimated present worth cost for this remedial action is \$5,200,000."

2. For site: REVERE TEXTILE PRINTS CORP, CTD004532610

Only 1 OU and would be considered a NFA Site

"The selected remedial action for this site includes no further action, with implementation of a 5-year sediment and ground water monitoring program. EPA has determined that the previous interim remedial activities have eliminated the need to conduct additional remedial actions and are adequate to protect human health and the environment. The estimated net present worth of this remedial action is \$263,000 for the site monitoring activities."

3. For site: Varsol Spill, FLD980602346

Only 1 OU and would be considered a NFA Site

“The selected remedial action for phase IV Includes adding air stripping to the existing water treatment system in the study area and operating the Miami Springs and Preston Municipal Wells for the dual purpose of providing potable water and recovering contaminated water from the aquifer. Total capital cost for the selected remedial alternative is estimated to be \$5,268,000 with O&M approximately \$334,400 per year.”

VI. 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 are from the IFMS database and 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.

A 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.

VII. 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. 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. An outline of their approach is as follows.

Geolytics mapped 1990 census tracts into 2000 census tracts using block level data. “The basic methodology,” the company writes, “was to use the smaller blocks to determine the population-weighted proportion of a 1990 tract that was later redefined as part of a 2000 tract.”³² A 1990 street coverage file

³² Appendix J: Description of Tract Remapping Methodology of Geolytics Data Users’ Guide for Neighborhood Change Database (1970-2000), page J3.

was used to weight populations of 1990 blocks included in 2000 census tracts when the 1990 blocks were split among multiple census tracts. The assumption is that local streets and roads served as a proxy for where populations were located. Block level data for 1980 were unavailable. This complicated the mapping of 1980 tracts into 1990 tracts. However, the correspondence between 1980 tracts and 1990 blocks is “very good”. As such “splitting a 1980 tract into 1990 tracts had to be done spatially, meaning based solely on the 1990 block to 1980 tract correspondence.”³³

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 February 2005, there are 4 sites from the 1982-3 sample that could not be placed in a census tract.³⁴ 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

³³ Ibid, page J4.

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.

census tract. In the next version of this paper, we will test whether the results are sensitive to this choice of the census tract.

VIII. 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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Table 1: Summary Statistics on the Superfund Program

	All NPL Sites w/ non-Missing House Price Data (1)	1982 HRS Sites w/ non-Missing House Price Data (2)	1982 HRS Sites w/ Missing House Price Data (3)
Number of Sites	985	487	188
1982 HRS Score Above 28.5	-----	306	95
<u>A. Timing of Placement on NPL</u>			
Total	985	331	111
# 1981-1985	406	311	97
# 1986-1990	443	17	11
# 1991-1995	73	2	1
# 1996-1999	63	1	2
<u>B. HRS Information</u>			
Mean Scores HRS \geq 28.5	41.89	44.47	43.23
Mean Scores HRS < 28.5	-----	15.54	16.51
<u>C. Size of Site (in acres)</u>			
Number of sites with size data	929	310	97
Mean (Median)	1,204 (29)	334 (25)	10,508 (35)
Maximum	198,400	42,560	405,760
<u>D. Stages of Clean-Up for NPL Sites</u>			
<u>Median Years from NPL Listing Until:</u>			
ROD Issued	-----	4.5	4.2
Clean-Up Initiated	-----	5.8	6.8
Construction Complete	-----	12.1	11.5
Deleted from NPL	-----	12.8	12.5
<u>1990 Status Among Sites NPL by 1990</u>			
NPL Only	392	98	30
ROD Issued or Clean-up Initiated	336	213	71
Construction Complete or Deleted	26	16	7
<u>2000 Status Among Sites NPL by 2000</u>			
NPL Only	130	15	3
ROD Issued or Clean-up Initiated	377	119	33
Construction Complete or Deleted	478	198	75
<u>E. Expected Costs of Remediation (Millions of 2000 \$'s)</u>			
# Sites with Nonmissing Costs	753	293	95
Mean (Median)	\$28.3 (\$11.1)	\$27.5 (\$15.0)	\$29.7 (\$11.5)
Mean Construction Complete	\$15.5	\$20.6	\$17.3
<u>F. Actual and Expected Costs Conditional on Construction Complete (Millions of 2000 \$'s)</u>			
Sites w/ Both Costs Nonmissing	476	203	69
Mean (Median) Expected Costs	\$15.5 (\$7.8)	\$20.6 (\$9.7)	\$17.3 (\$7.3)
Mean (Median) Actual Costs	\$21.6 (\$11.6)	\$32.0 (\$16.2)	\$23.3 (\$8.9)

Notes: All dollar figures are in 2000 \$'s. Column (1) includes information for sites placed on the NPL before 12/31/99. 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	181	306	90	137	47,698	-----	-----	-----
<u>Superfund Clean-up Activities</u>								
Ever NPL by 1990	0.1271	0.9869	0.2222	0.9854	-----	-----	0.0000	0.0000
Ever NPL by 2000	0.1602	0.9869	0.2667	0.9854	-----	-----	0.0000	0.0000
<u>Own Tract Housing Prices</u>								
1980 Mean	45,027	52,137	46,135	50648	68,970	0.0000	0.0002	0.0839
1990 Median	80,185	96,752	84,461	91611	99,160	0.5464	0.0047	0.4332
2000 Median	115,479	135,436	117,528	123503	150,692	0.0001	0.0008	0.4490
<u>Adjacent Tracts Housing Prices</u>								
1980 Mean	49,324	62,711	48,735	54,078	68,970	0.3384	0.0380	0.0470
1990 Median	85,476	98,743	85,793	88,743	99,160	0.8992	0.0094	0.6533
2000 Median	122,337	140,841	122,776	131,125	150,692	0.0105	0.0020	0.2771
<u>Demographics & Economic Characteristics</u>								
Population Density	1670	1157	1361	1151	5388	0.0000	0.0673	0.5704
% Black	0.1126	0.0713	0.0819	0.0844	0.1164	0.0000	0.0366	0.9259
% Hispanic	0.0443	0.0424	0.0309	0.0300	0.0716	0.0000	0.8406	0.9281
% Under 18	0.2932	0.2936	0.2885	0.2934	0.2797	0.0000	0.9577	0.5682
% Female Head HH	0.1879	0.1576	0.1639	0.1664	0.1894	0.0000	0.0172	0.8619
% Live Same House 5 Yrs Ago	0.6025	0.5623	0.5854	0.5655	0.5154	0.0000	0.0011	0.2438
% > 25 No HS Diploma	0.4053	0.3429	0.3881	0.3533	0.3148	0.0003	0.0000	0.0599
% > 25 BA or Better	0.1029	0.1377	0.1092	0.1343	0.1743	0.0000	0.0000	0.0355
% < Poverty Line	0.1139	0.1005	0.1072	0.1115	0.1124	0.0079	0.1088	0.7158
% Public Assistance	0.0885	0.0745	0.0805	0.0755	0.0763	0.6322	0.0408	0.5780
Average HH Income	19635	20869	19812	20301	21500	0.0583	0.0130	0.4857
<u>Housing Characteristics</u>								
Total Housing Units	1357	1353	1367	1319	1349	0.9073	0.9506	0.5753
% Owner Occupied	0.6792	0.6800	0.6942	0.6730	0.6196	0.0000	0.9594	0.3444
% 0-2 Bedrooms	0.4691	0.4439	0.4671	0.4496	0.4680	0.0131	0.1034	0.4166
% 3-4 Bedrooms	0.5098	0.5284	0.5089	0.5199	0.5055	0.0122	0.2094	0.5864
% Built Last 5 Years	0.1185	0.1404	0.1366	0.1397	0.1544	0.0458	0.0498	0.8444
% Built Last 10 Years	0.2370	0.2814	0.2673	0.2758	0.2888	0.4914	0.0117	0.7233
% No Air Conditioning	0.5058	0.4801	0.5157	0.5103	0.4274	0.0002	0.2528	0.8700

% with Zero Full Baths	0.0315	0.0259	0.0339	0.0290	0.0230	0.1115	0.0890	0.3859
% Units Detached	0.8585	0.8908	0.8545	0.8897	0.8791	0.1331	0.0496	0.1068
% Units Attached	0.0603	0.0307	0.0511	0.0317	0.0713	0.0000	0.0402	0.2973
% Mobile Homes	0.0813	0.0785	0.0944	0.0787	0.0496	0.0000	0.7924	0.2846

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. The Panel title "Adjacent Tracts Housing Price" reports the mean housing prices in all tracts that share a border with the tract containing the hazardous waste site. All other entries in the table refer to characteristics of the tract where the site is located. P-values less than .01 are denoted in bold. For the 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 the Presence of a NPL Hazardous Waste Site and the ln of Median Census Tract Housing Prices, 1990 and 2000

	(1)	(2)	(3)	(4)
<u>A. Own Census Tract</u>				
<u>ln (1990 Median Price)</u>				
1(NPL Status by 1990)	0.118 (0.023)	0.146 (0.021)	0.149 (0.020)	0.089 (0.018)
<u>ln (2000 Median Price)</u>				
1(NPL Status by 2000)	0.038 (0.012)	0.043 (0.011)	0.068 (0.010)	0.059 (0.009)
<u>B. Adjacent Census Tracts</u>				
<u>ln (1990 Median Price)</u>				
1(NPL Status by 1990)	0.152 (0.018)	0.096 (0.010)	0.080 (0.023)	0.045 (0.017)
<u>ln (2000 Median Price)</u>				
1(NPL Status by 2000)	0.039 (0.011)	0.102 (0.034)	0.089 (0.026)	0.072 (0.023)
1980 Prices	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes
1980 Demographics	No	No	Yes	Yes
State Fixed Effects	No	No	No	Yes

Notes: The table reports results from 16 separate regressions where the unit of observation is a census tract. The sample size is 48,262 in all regressions. 47,508 (47,272) of these observations are from the census tracts without a NPL hazardous waste site in 1990 (2000). In Panel A, the remaining 754 (985) observations in 1990 (2000) are from census tracts that contain a hazardous waste site that had ever been on the NPL at the time of the housing price observation. In Panel B, these observations are replaced with averages across all census tracts with complete housing price data that share a border with the tract containing the site. The dependent variables are underlined in the first column. The entries report the coefficient and heteroskedastic-consistent standard error (in parentheses) on the NPL indicator. The controls are listed in the row headings at the bottom of the table. See the text and Data Appendix for further details.

Table 4: Estimates of the First-Stage Relationship and an Informal Validity Test

	(1)	(2)	(3)	(4)	(5)	(6)
<u>A. First Stage:</u>						
<u>Association Between Instrument and NPL Status</u>						
<u>1(NPL Status by 1990)</u>						
1(1982 HRS Score > 28.5)	0.861 (0.026)	0.856 (0.027)	0.847 (0.028)	0.840 (0.031)	0.671 (0.063)	0.728 (0.057)
<u>1(NPL Status by 2000)</u>						
1(1982 HRS Score > 28.5)	0.825 (0.029)	0.820 (0.029)	0.810 (0.030)	0.799 (0.035)	0.608 (0.066)	0.687 (0.060)
<u>B. Informal Validity Test:</u>						
<u>Association Between Instrument and ln (1980 Mean House Price)</u>						
<u>Own Census Tract</u>						
1(1982 HRS Score > 28.5)	-----	0.035 (0.027)	0.001 (0.021)	-0.010 (0.018)	-0.004 (0.029)	-0.008 (0.021)
<u>Adjacent Census Tracts</u>						
1(1982 HRS Score > 28.5)	-----	0.039 (0.031)	0.016 (0.026)	0.010 (0.022)	-0.003 (0.039)	0.023 (0.026)
1980 Prices	Yes	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes	Yes
Quadratic in 1982 HRS Score	No	No	No	No	Yes	No
Regression Discontinuity Sample	No	No	No	No	No	Yes

Notes: The table reports results from 22 separate regressions. The sample size is 487 in all regressions in columns (1)-(5), 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 (6) limits the sample to tracts (or neighbors of tracts) with sites with initial HRS scores between 16.5 and 40.5 and totals 227 census tracts. In Panel A, the dependent variables are indicators for whether the hazardous waste sites had been placed on the NPL by 1990 and 2000, respectively. In Panel B, the dependent variables are the ln of 1980 mean housing prices in the tract with the hazardous waste site and the ln of the mean of the mean house price across the census tracts that share a border with the tract containing the NPL site, respectively. 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 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)	(6)
<u>A. Own Census Tract</u>						
<u>1990</u>						
1(NPL Status by 1990)	0.034 (0.062)	0.066 (0.057)	0.064 (0.055)	0.020 (0.054)	-0.006 (0.122)	-0.006 (0.078)
<u>2000</u>						
1(NPL Status by 2000)	0.037 (0.036)	0.043 (0.031)	0.056 (0.029)	0.047 (0.027)	0.007 (0.063)	0.027 (0.038)
<u>B. Adjacent Census Tracts</u>						
<u>1990</u>						
1(NPL Status by 1990)	0.068 (0.048)	0.060 (0.039)	0.012 (0.033)	-0.006 (0.027)	-0.005 (0.059)	-0.020 (0.044)
<u>2000</u>						
1(NPL Status by 2000)	0.069 (0.035)	0.019 (0.029)	0.014 (0.025)	0.012 (0.022)	0.021 (0.054)	0.011 (0.035)
1980 Ln House Price	Yes	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes	Yes
Quadratic in 1982 HRS Score	No	No	No	No	Yes	No
Regression Discontinuity Sample	No	No	No	No	No	Yes

Notes: The entries report the results from 24 separate regressions, where a census tract is the unit of observation. The samples sizes are 487 in columns (1) through (5) and 227 in column (6). 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. See the notes to Table 4, the text and the Data Appendix for further details.

Table 6: Two-Stage Least Squares Estimates of Stages of Superfund Clean-ups on House Prices

	(1)	(2)	(3)	(4)	(5)	(6)
<u>Ln (1990 Median House Price)</u>						
1(NPL Only) [112 Sites, Mean HRS = 40.7]	0.072 (0.077)	0.061 (0.071)	0.035 (0.068)	0.003 (0.063)	-0.054 (0.120)	-0.044 (0.096)
1(ROD & Incomplete Remediation) [197 Sites, Mean HRS = 44.8]	0.004 (0.065)	0.052 (0.060)	0.072 (0.058)	0.004 (0.055)	-0.055 (0.113)	-0.015 (0.079)
1(Const Complete or NPL Deletion) [16 Sites, Mean HRS = 35.3]	0.097 (0.210)	0.045 (0.165)	0.009 (0.172)	0.073 (0.166)	0.019 (0.199)	0.120 (0.175)
P-Value from F-Test of Equality	0.60	0.99	0.78	0.91	0.90	0.60
<u>Ln (2000 Median House Price)</u>						
1(NPL Only) [21 Sites, Mean HRS = 37.1]	0.124 (0.112)	0.064 (0.079)	0.017 (0.069)	0.036 (0.056)	-0.008 (0.078)	-0.028 (0.084)
1(ROD & Incomplete Remediation) [113 Sites, Mean HRS = 44.2]	0.084 (0.040)	0.051 (0.037)	0.065 (0.034)	0.013 (0.031)	-0.035 (0.065)	-0.027 (0.053)
1(Const Complete or NPL Deletion) [198 Sites, Mean HRS = 42.1]	0.014 (0.036)	0.039 (0.032)	0.056 (0.031)	0.063 (0.029)	0.018 (0.060)	0.043 (0.040)
P-Value from F-Test of Equality	0.08	0.91	0.76	0.20	0.19	0.30
1980 Prices/Rental Rate	Yes	Yes	Yes	Yes	Yes	Yes
1980 Housing Char's	No	Yes	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes	Yes
Quadratic in 1982 HRS Score	No	No	No	No	Yes	No
Regression Discontinuity Sample	No	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 were "construction complete" or deleted from the NPL, respectively. The instruments are the interactions of the indicator for a 1982 HRS score above 28.5 and these three independent indicators. The table reports the instrumental variables parameter estimates and heteroskedastic consistent standard errors for the three indicators of clean-up status. The table also reports the p-value associated with a F-test that the three parameters are equal. The sample sizes are 487 in columns (1) through (5) and 227 in column (6).

Table 7: Instrumental Variables Estimates of 2000 NPL Status on the Population and their Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
<u>A. Housing Units and Population Outcomes</u>						
<u>Total Housing Units</u>						
1(Ever NPL as of 2000)	238	143	127	118	43	77
[1980 Mean = 1354]	(69)	(61)	(62)	(71)	(168)	(113)
<u>Population</u>						
1(Ever NPL as of 2000)	617	329	308	301	660	400
[1980 Mean = 3756]	(188)	(168)	(167)	(184)	(444)	(288)
<u>B. Residents' Wealth Outcomes</u>						
<u>% Public Assistance</u>						
1(Ever NPL as of 2000)	-0.016	-0.014	-0.014	-0.010	-0.000	-0.001
[1980 Mean = 0.079]	(0.005)	(0.005)	(0.005)	(0.005)	(0.012)	(0.007)
<u>% BA or Better</u>						
1(Ever NPL as of 2000)	0.014	0.013	0.019	0.017	0.017	0.012
[1980 Mean = 0.124]	(0.011)	(0.010)	(0.009)	(0.011)	(0.023)	(0.013)
<u>C. Demographic/Environmental Justice Outcomes</u>						
<u>% Black</u>						
1(Ever NPL as of 2000)	-0.022	-0.015	-0.011	-0.003	0.009	-0.000
[1980 Mean = 0.087]	(0.012)	(0.010)	(0.010)	(0.011)	(0.023)	(0.015)
<u>% Hispanic</u>						
1(Ever NPL as of 2000)	-0.001	0.001	0.001	-0.009	-0.000	-0.002
[1980 Mean = 0.043]	(0.008)	(0.008)	(0.008)	(0.008)	(0.020)	(0.014)
<u>% Population Under Age 6</u>						
1(Ever NPL as of 2000)	-0.004	-0.004	-0.003	-0.003	0.002	0.000
[1980 Mean = 0.086]	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)	(0.004)
1980 Dependent Variable	Yes	Yes	Yes	Yes	Yes	Yes
1980 Prices & Housing Char's	No	Yes	Yes	Yes	Yes	Yes
1980 Economic Conditions	No	No	Yes	Yes	Yes	Yes
1980 Demographics	No	No	Yes	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes	Yes
Quadratic in 1982 HRS Score	No	No	No	No	No	No
Reg Discontinuity Sample	No	No	No	No	Yes	Yes

Notes: The entries report the results from 48 separate instrumental variables regressions. All outcomes are measured in 2000. The 1980 means of the dependent variable are 1354, 3,756, 0.079, 0.124, 0.087, 0.043, and 0.086. The sample size is 487 in columns (1)-(5) and 227 in columns (6). The observations are from census tracts containing a hazardous waste site that received a 1982 HRS score. See text and Notes to Table 5 for further details.

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

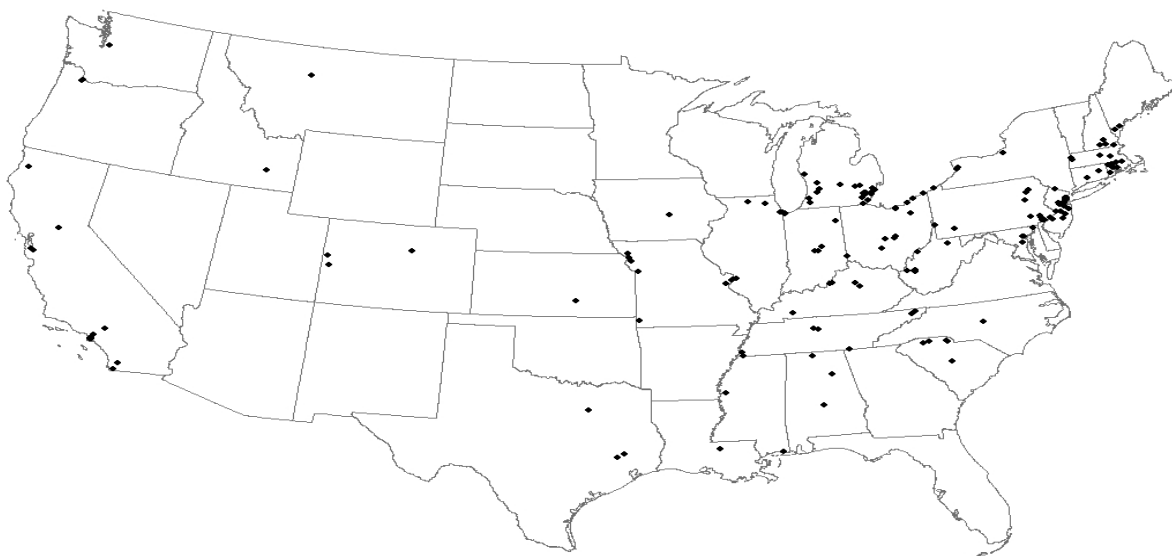


Notes: "All NPL" sample is comprised of the 985 NPL sites with nonmissing housing price data in 1980, 1990, and 2000 that were placed on the NPL by January 1, 2000.

Figure 2: Geographic Distribution of Hazardous Waste Sites in 1982 HRS Sample
A. Sites with 1982 HRS Scores Exceeding 28.5

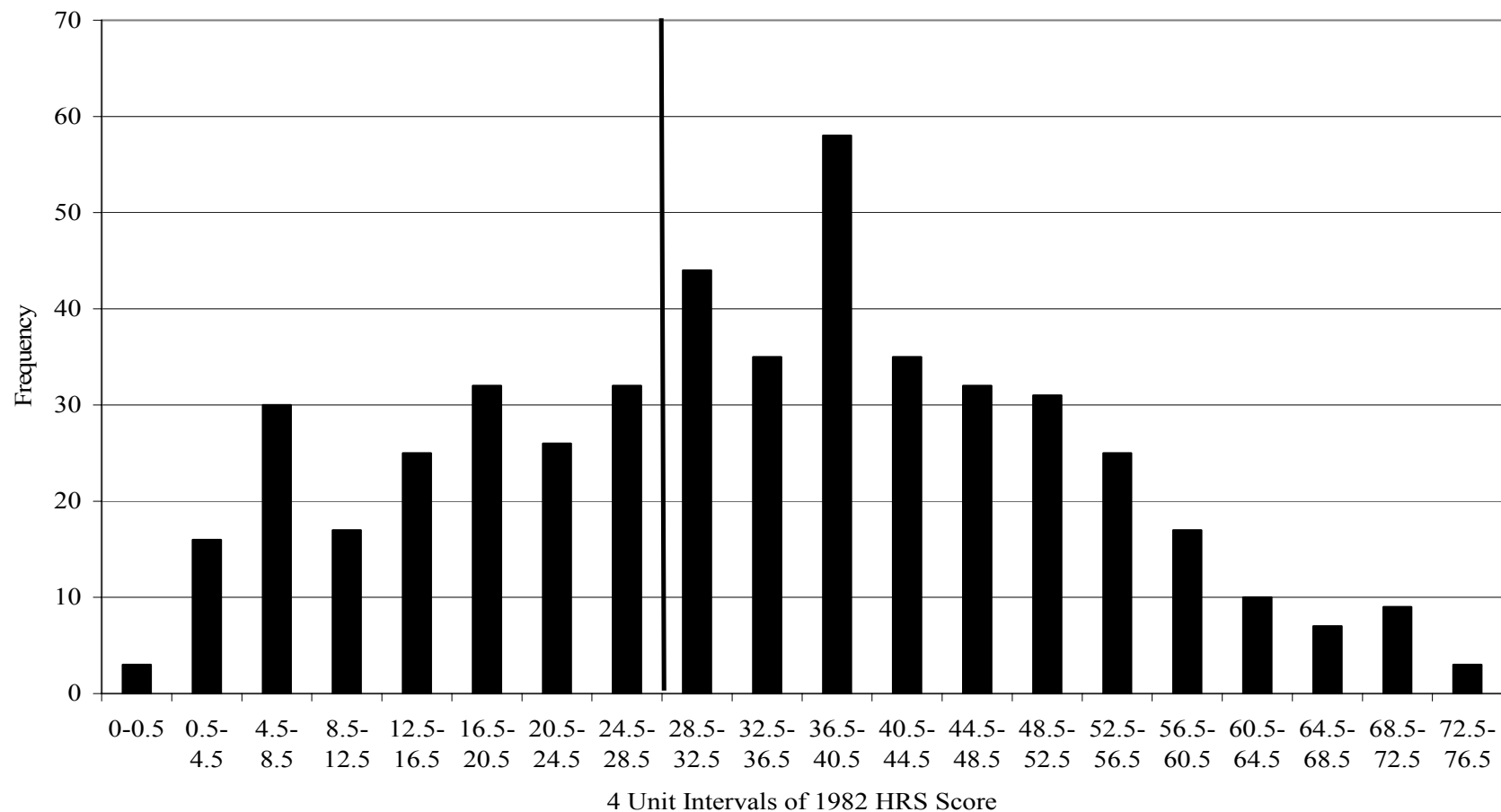


B. Sites with 1982 HRS Scores Below 28.5



Notes: The “1982 HRS” sample is comprised of the 487 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 487 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 188 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

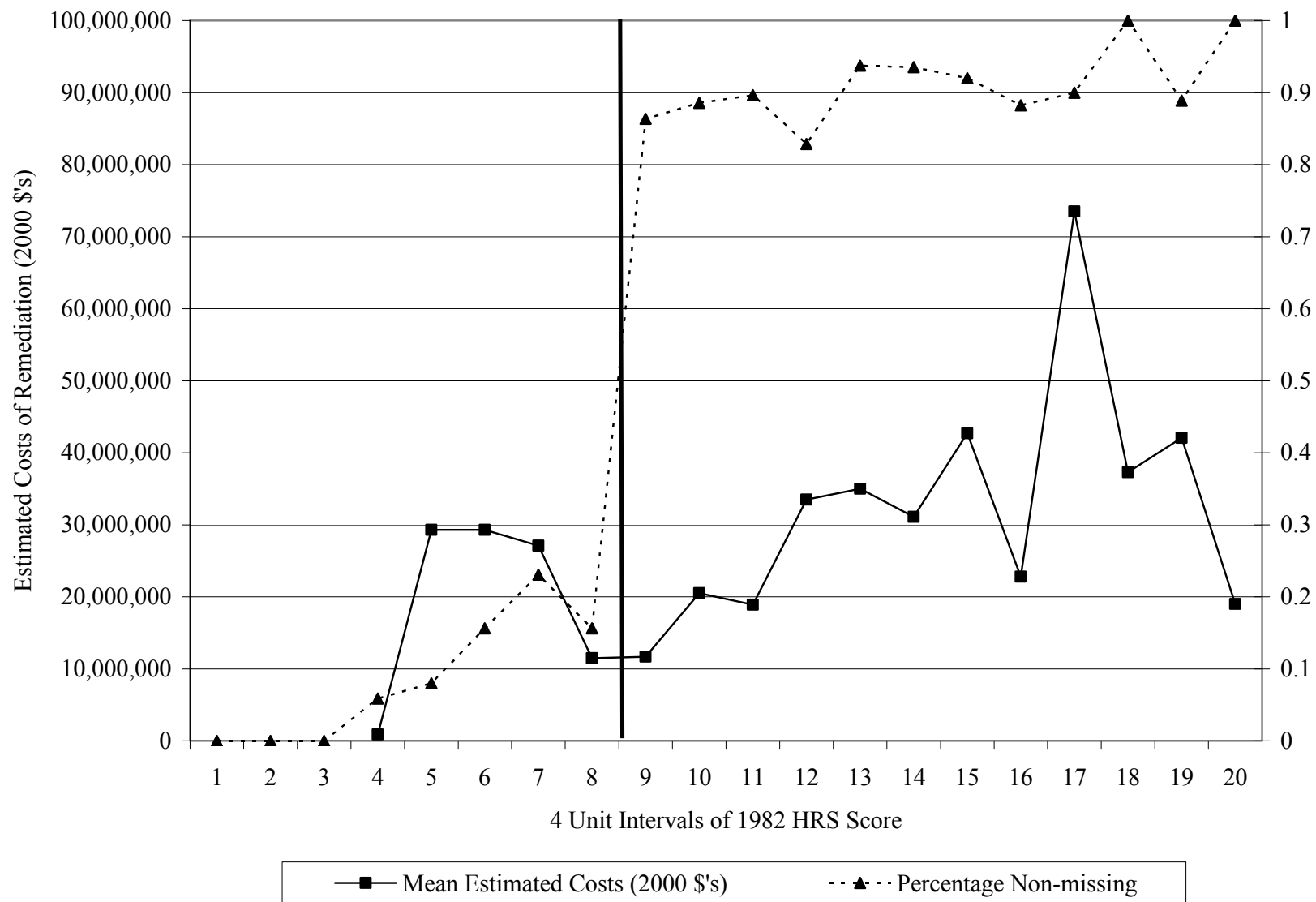
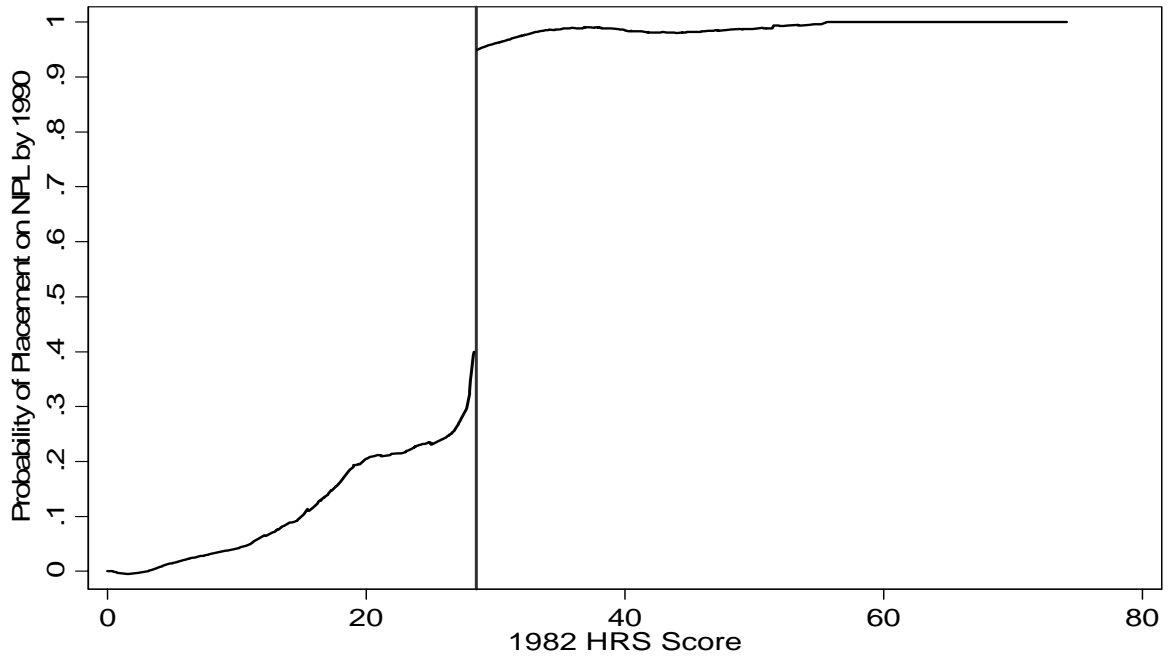
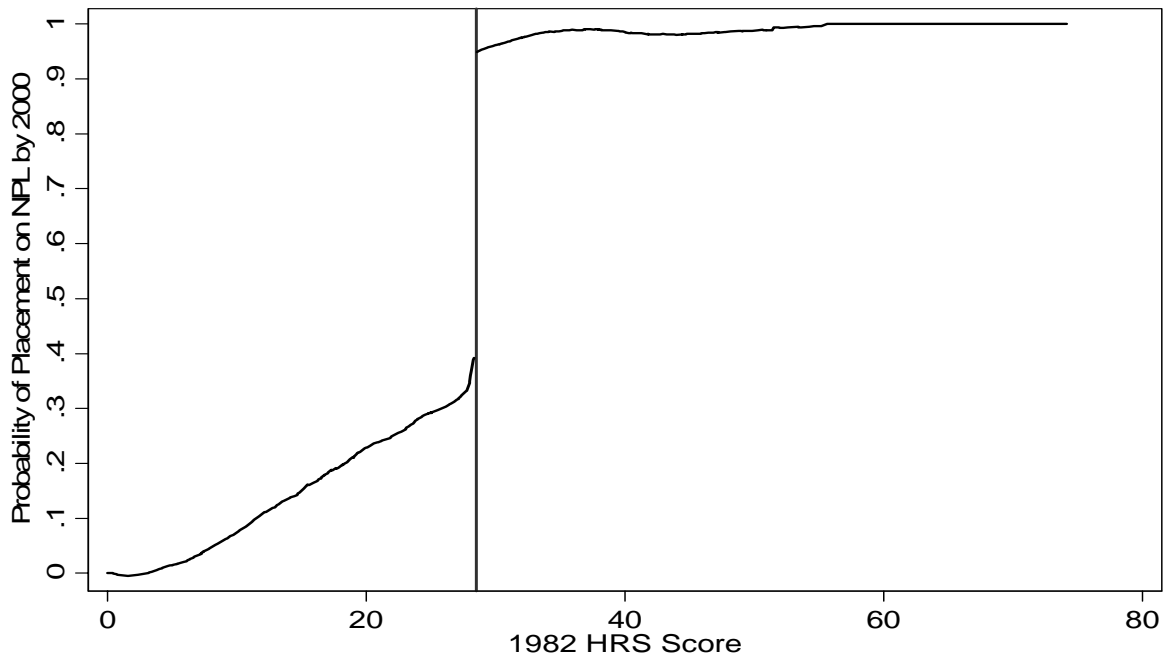


Figure 5: Probability of Placement on the NPL by 1982 HRS Score
A. NPL Status by 1990

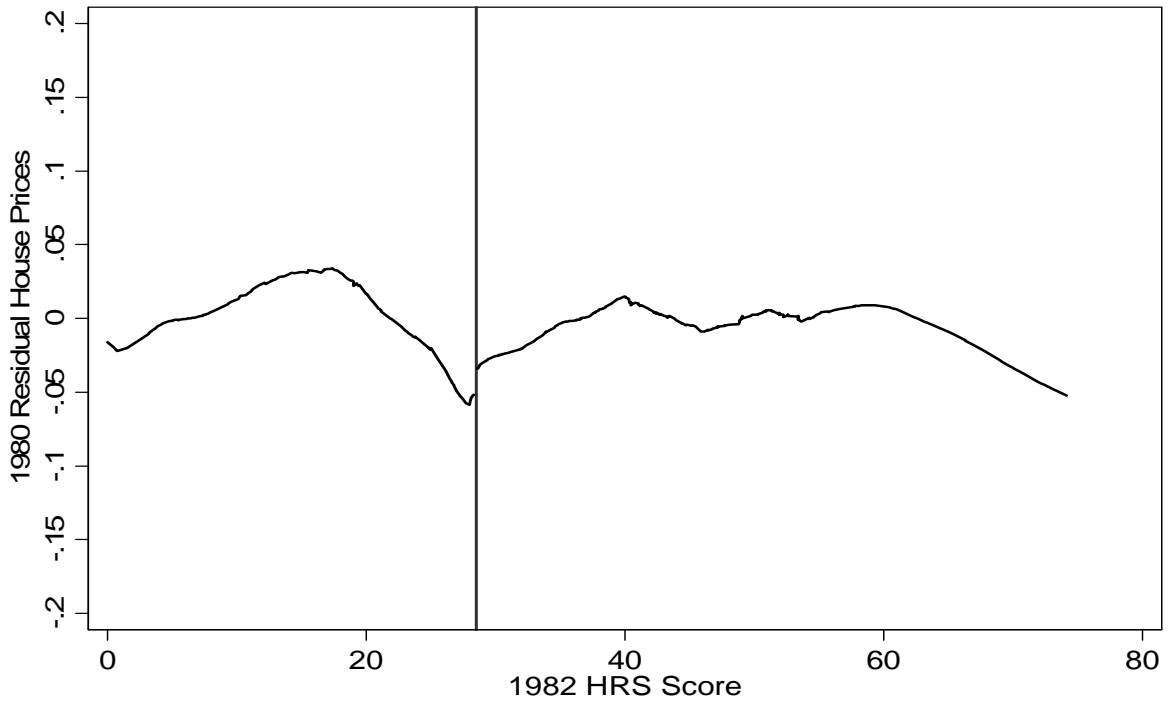


B. NPL Status by 2000

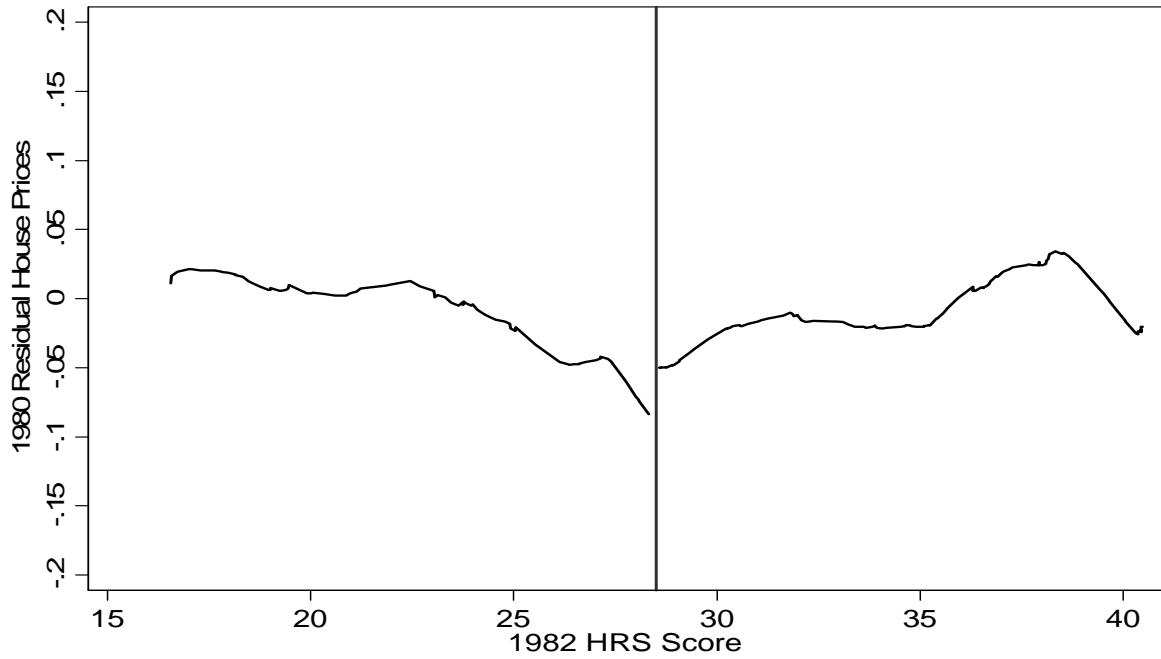


Notes: To Come

Figure 6: Own Tract 1980 Residual House Prices After Adjustment for Column 4 Covariates
A. Full 1982 HRS Sample

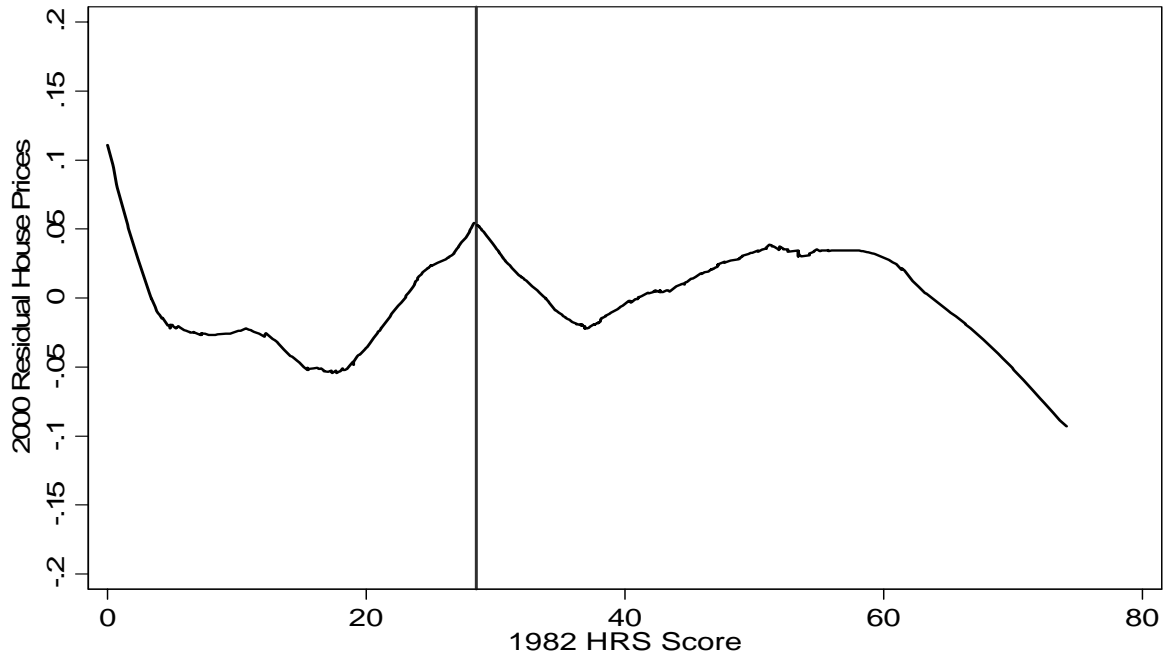


B. Regression Discontinuity Sample

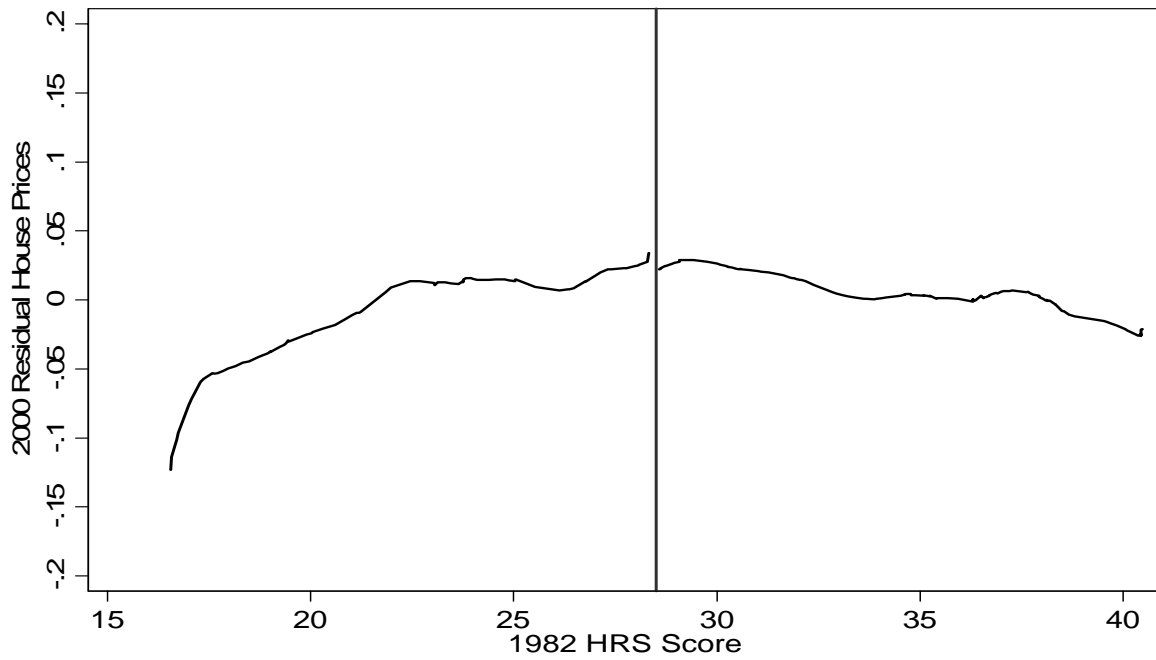


Notes: To come

Figure 7: Own Tract 2000 Residual House Prices After Adjustment for Column 4 Covariates
A. Full 1982 HRS Sample

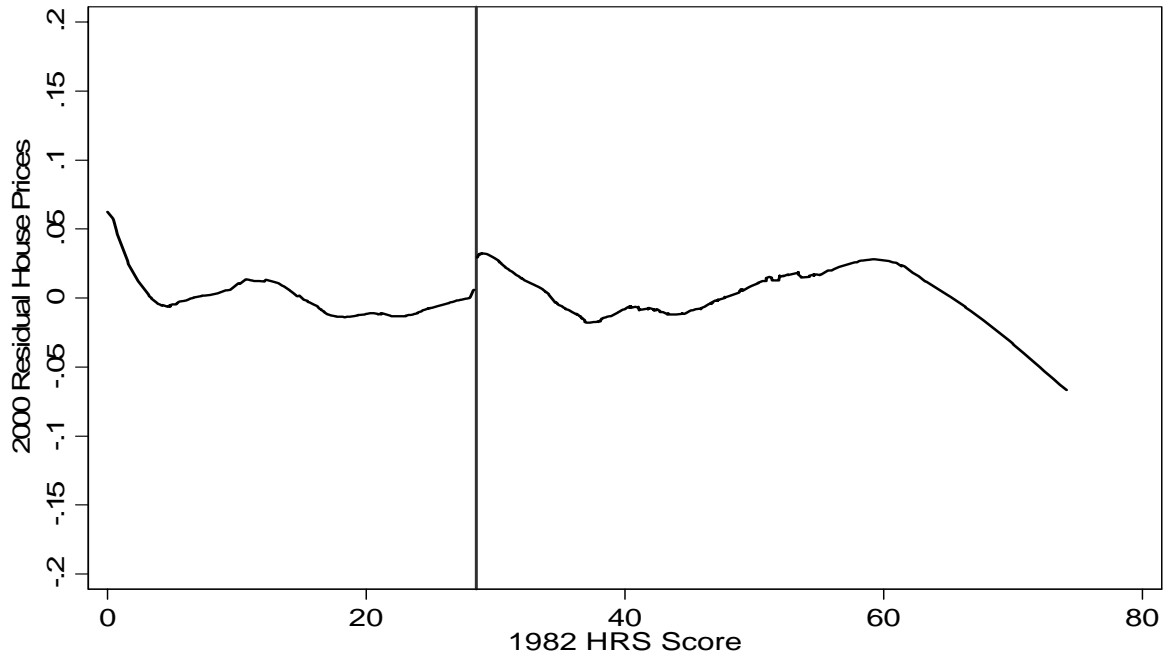


B. Regression Discontinuity Sample

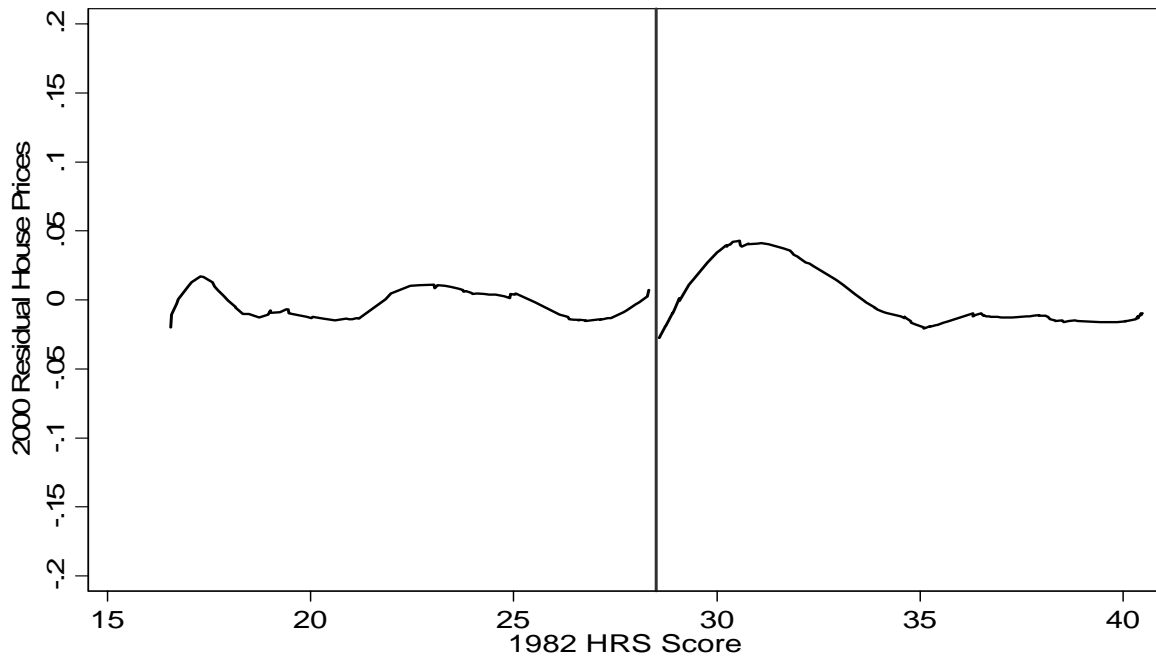


Notes: To come

Figure 8: Adjacent Tracts 2000 Residual House Prices After Adjustment for Col 4 Covariates
A. Full 1982 HRS Sample



B. Regression Discontinuity Sample



Notes: