Evidence of Environmental Migration: Housing values alone may not capture the full effects of local environmental disamenities

by

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ABSTRACT

In hedonic property value models, economists typically assume that changing perceptions of environmental risk should be captured by changes in housing prices. However, for long-lived environmental problems, we find that many other features of neighborhoods seem to change as well, because households relocate in response to changes in perceived environmental quality. We consider spatial patterns in census variables over three decades in the vicinity of four Superfund sites. We find many examples of moving and staying behavior, inferred from changes in the relative concentrations of a wide range of socio-demographic groups in census tracts near the site versus farther away.

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I. Introduction

Hedonic property value models have long been used in attempts to quantify the social costs of environmental contamination or the potential social benefits from remediation. Many early studies employed cross-sectional data, or at least data on a large number of housing transactions occurring over a relatively short period of time. In recent years, however, more attention has been devoted to the problem of readjustment to equilibrium following some environmental shock to local housing markets. While the month-to-month rental housing market may be relatively quick to adjust to environmental shocks, it is likely that the adjustment time for owner-occupied housing will be considerably longer, given the substantial transactions costs of moving (Venti and Wise (1984), Nordvik (2001)).

This paper contributes to the literature on indirect market valuation of changes in environmental quality by examining more closely the process of neighborhood adjustment to an environmental shock. Housing prices reflect the heterogeneous mix of structural attributes, neighborhood characteristics, and local public goods available in the market. Household preferences with respect to these goods also vary widely. Hedonic property value models that are estimated over a short time interval may not fully capture the re-equilibration process and can produce misleading estimates of changes in social welfare attributed to environmental hazards. The consequences of an "environmental hazard" should perhaps be defined more broadly—to include not just the initial risk in the form of possible exposure to toxic substances, but also the full complement of adverse neighborhood changes (either temporary or permanent) that may ensue as a consequence of the identification of this risk (see Greenberg and Schneider (1999)).

Environmental quality has been incorporated into residential property value models since Ridker and Henning (1967).[1] While simple hedonic models that explain housing prices—as a function of housing and neighborhood attributes—are the first key step in any welfare analysis, these first-stage models are only useful for assessing the welfare effects of *marginal* changes in air quality, all else held constant. Welfare analysis for non-marginal changes requires a full marginal WTP function. But non-marginal changes, in the form of the identification of a Superfund site for example, can trigger a whole host of behavioral responses in neighborhoods that evolve over time. Initially, the identification of a local environmental hazard may have an extremely negative effect on local housing prices. However, as households with strong preferences for environmental quality relocate farther away from the site, and as households with less disutility from environmental risks move into the area, housing prices will adjust. It is almost certainly the case that the "impact" effect upon welfare of a sudden change in perceived environmental quality will be greater than the overall effect after households have moved and re-established locational equilibrium. One would expect that overall local welfare would be lower than before the change in perceived environmental quality, but not as low as before the spatial re-sorting of households has taken place.

Sieg, et al. (2002) and Sieg, et al. (2004) have introduced the idea of locational equilibrium to analyses of the effects of changes in the level of local public goods (i.e. ozone concentrations) on housing markets. Smith, et al. (2004) acknowledge that policy analysis often requires an analytical framework that is capable of measuring the benefits from large and often spatially diverse changes in environmental amenities. These researchers emphasize that "Households can adjust to changes in a spatially delineated good by moving."[2] Walsh (2003) also acknowledges the role of in-migration and out-migration in the determination of equilibrium housing prices in a paper that addresses the role of open space in the intra-metropolitan location decisions of households.

We seek explicit evidence of the nature of residential mobility in response to the identification of significant localized environmental hazards. We choose four different

Superfund localities with relatively high Hazard Ranking System (HRS) scores: Old Bethpage Landfill on Long Island (included among the sites examined by Cameron and Crawford (2004)), two sites that have been studied in the environmental economics literature--Tacoma's copper smelter (studied by McMillen (2003)), and the RSR Lead Smelter in Dallas (studied by Dale, et al. (1999) and McCluskey and Rausser (2003))-- and the notorious Love Canal site (described by Fletcher (2002), and Fletcher (2003)). We follow these localities across four census years (1970, 1980, 1990 and 2000), looking for statistically significant *shifts* in the relative levels of variables near the site as opposed to farther away, but still within a roughly 12-kilometer radius of the site itself. We cannot consider the complete list of long-form census variables for 2000 because conformable data are not available all the way back to 1970, but we are able to consider many: age distributions, some aspects of income distributions, family structure, ethnic composition, housing tenure, and recent mobility. We model each of these sociodemographic and housing variables, at the census tract level, as a function of distance from the localized environmental disamenity represented by each Superfund site.

Previous work in the environmental justice literature, notably Been and Gupta (1997), has compared the values of income and ethnicity variables for tracts that include noxious facilities against the values of these variables for other randomly selected tracts around the country that do not contain such facilities. In some of this literature, it has been difficult to identify relationships between environmental quality and sociodemographics that generalize readily across all sites and all regions. Part of this difficulty may stem from heterogeneity in both the type of environmental threat and the neighborhood where it emerges. Greenstone and Gallagher (2004) have compare National Priorities List (NPL) sites that were designated for cleanup against those which were not designated. In the research reported in this paper, we elect instead to study just a handful of Superfund sites and use more-distant census tracts in the same locality as controls.[3] Rather than considering all sites and assuming one underlying basic relationship between the Superfund process and tract-level sociodemographics, we construct a separate model for each of our sites so that heterogeneity is broadly accommodated. Across these models, we then look for robust similarities and important differences in the evolution of distance profiles over time.

Greenstone and Gallagher (2004) make the provocative finding that even their largest estimates of "the benefits of Superfund clean-ups are smaller than the mean expected costs (i.e. before initiation of any clean-up activities) of $28 million per clean-up." Their model explains a generalized difference in census tract log-median property values between 1980 and 1990 as a function of NPL status in 1990, controlling for other census-tract level characteristics in 1980, recognizing the potential endogeneity of 1990 NPL status. They restrict their other census-tract characteristics to just the 1980 values "to avoid confounding the effect of NPL status with 'post-treatment' changes in these variables that may be due to NPL status."[4]

However, it is likely that the listing of a site on the NPL in 1983 sets in motion a whole variety of 'post-treatment' changes in sociodemographic variables that also affect property values by 1990. Schachter and Kuenzi (2002) describe statistics on the duration in residence in the US according to the 1996 Survey of Income and Program Participation (SIPP) data from the Census Bureau. The overall median duration is just 4.7 years, but moving behavior is closely tied to age and varies considerably with marital status, the presence of children, income, and of course type of tenure (ownership/rental). Greenstone and Gallagher (2004) report that the median time between NPL placement and initiation of clean-up is between six and seven years, and the median time to a "construction complete" assessment is twelve years. These lags leave plenty of time for people who are concerned about any environmental threats presented by the yet-unremediated sites to move elsewhere, even if they do not relocate any sooner than they would otherwise have chosen to move.

Systematic patterns of migration by groups that are more and less sensitive to environmental threats can produce differences over time in the sociodemographic composition of neighborhoods. If these changes collectively exacerbate the negative effect on property values that is precipitated by listing, the apparent effect of the listing will be exaggerated. Alternately, if these changes collectively offset at least some of the negative effects of the listing event, the effect of listing on property values will be underestimated. Of course, the characteristic we would most like to know, “subjective sense of risk from the environmental hazard in question,” is not measured by the census. If people whose welfare is most affected by perceived exposure to environmental contaminants move out, and other people whose welfare is least affected by perceived exposure move in, then this heterogeneity in preferences, coupled with migration patterns, can conceivably mean that attention only to changes in housing prices (in the tract or tracts immediately surrounding the site) will lead the investigator to miss some of the broader general equilibrium and dynamic distributional welfare consequences of the Superfund identification and cleanup process.

Our goal in this paper is to identify some of the sociodemographic migration patterns that appear to be precipitated by the identification and remediation of a Superfund site. Section 2 of this paper outlines the empirical specifications that we use to ascertain whether the concentrations of certain socioeconomic groups in census tracts near each Superfund site change differently over time than do these same concentrations in census tracts that are farther away from the site. Section 3 describes the available data. Section 4 presents our empirical results, primarily in the form of a summary table containing triples of symbols that depict the statistically significant estimates for just the three key parameters from each of a large number of regressions. Section 5 offers a number of caveats and our basic conclusions.

II. Empirical Models

The empirical models employed in this paper are extremely straightforward. Given that our data are aggregated at the level of the census tract, we cannot consider the characteristics of individual dwellings, as one might do for a hedonic property value model. Instead, we consider a whole host of census tract attributes, not just median housing price, to be jointly endogenous. We take the locations of the tracts, relative to the Superfund site and relative to other local amenities/disamenities, to be exogenous and estimate a series of reduced form models for an array of 22 tract-level characteristics. Also taken as exogenous are variables such as the time of revelation of the environmental threat, the time of the listing of the site on the NPL, and the pace of cleanup.[5] While one might anticipate correlations across the error terms in these 22 equations, the regressors are identical for each equation (within a case), so no efficiency gains can be expected from generalizing to seemingly unrelated regression (SUR) estimation methods. We thus estimate each regression model independently.

Basic Specification: We wish to examine what happens, over time, to the distance profile for the proportion of each census tract's population in a given category. For each site, we use data for census tracts $i = 1,...,N$ and for census years 1970 through 2000, denoted as $t = 0,1,2,3$. If distance is a proxy for perceived exposure, the potential for differences in proximity to a Superfund site to have an effect on the characteristics of a census tract should diminish with distance from the Superfund site. Thus, we model the proportion of the population in a particular category, $\%X_{it}$, as a function of the reciprocal of the distance from the site, $(1/d_{it})$:

$$\%X_{it} = \beta_0 + \beta_1 \left(1/d_i\right) + \varepsilon_{it} \qquad (1)$$

If, as so many other studies have done, we were simply looking for current-period patterns around our Superfund sites in the percentages of census tract populations in particular socio-demographic groups (such as the percentages of African-Americans or Hispanics, or the percentage of children or seniors) we would be looking for nonzero estimates of the simple scalar parameter β_1. In this reciprocal specification, a positive value for this coefficient implies that the proportion in question declines with distance from the site, while a negative coefficient implies that this proportion increases with distance. A reciprocal form is appealing in that as distance increases, the fitted value of $\%X_{it}$ becomes asymptotic to β_0, which we interpret as "the prevailing average level of $\%X$ in the surrounding community."

In this study, however, we are not concerned with the *initial* spatial pattern of socioeconomic characteristics relative to the location of the Superfund site. The question is not whether β_1 is positive or negative--we do not care if the initial pattern has a larger or smaller proportion of a given group nearer the site versus farther away. Instead, we wish to know how these spatial patterns *change* over time in response to changes in the (perceived) level of an environmental risk. We are interested in knowing whether a particular group becomes relatively more or less concentrated near the site over time, regardless of the slope of the initial (1970) distance profile. We wish to abstract from changes in the overall prevalence of the group across the wider area and to focus on *changes* in the relative concentration of groups near the site versus farther away, but still in the same area. This question requires spatial data collected over time, as perceived risks change.

Each of our Superfund sites, with the exception of the Dallas RSR smelter, was listed on the initial National Priorities List in 1983 or shortly thereafter. If the listing time corresponded to the first publicly available information about the hazard associated with the site, one would expect that there should be little movement of a particular group relative to the site prior to its listing. However, local area residents may have been well aware of the hazards prior to listing, and environmental advocacy groups in each area may have publicized the problems that led to the placement of the site on the NPL. Spatial equilibrium may have been adjusting continuously prior to listing so that no sudden and new information is contained in the NPL listing event itself. None of the Superfund sites in our sample had been delisted by the year 2000. Officially, therefore, all of these sites were still contaminated at the time of the 2000 census. However, cleanup will have been proceeding to different degrees at each site, and people may have begun making longer-term housing decisions in anticipation of delisting at some time in the near future. Thus, we need to allow for bi-directional, as well as just uni-directional, shifts in our distance/perceived-risk profiles over time.

The model in (1) implies that the distance profile is constant across all four decades in our sample. To explore the possibility that the coefficient β_1 is not a simple constant, but instead a nonlinear function of time t, where $t = 0,\ 1,\ 2,$ and 3 (a function that has the flexibility to change arbitrarily over the census years in our study), the slope parameter can be generalized.

Differenced Model. Let $\%X_{i70}, \%X_{i80}, \%X_{i90}, \%X_{i00}$ represent the percent of the population in group X in each of the last four census years. If we allow $1/d_i$ to have a different effect on $\%X_{it}$ in each census year, then the implied model in each of the four separate years will be:

$$\begin{aligned} \%X_{i70} &= \beta_{00} + \beta_{10}\left(1/d_i\right) + \varepsilon_{i70} \\ \%X_{i80} &= \beta_{01} + \beta_{11}\left(1/d_i\right) + \varepsilon_{i80} \\ \%X_{i90} &= \beta_{02} + \beta_{12}\left(1/d_i\right) + \varepsilon_{i90} \\ \%X_{i00} &= \beta_{03} + \beta_{13}\left(1/d_i\right) + \varepsilon_{i00} \end{aligned} \qquad (1)$$

If we difference the data between successive census years, we get:

$$
\begin{aligned}
\Delta\%X_{i80} &= \%X_{i80} - \%X_{i70} = \left(\beta_{01}-\beta_{00}\right) + \left(\beta_{11}-\beta_{10}\right)\left(1/d_i\right) + \left(\varepsilon_{i80}-\varepsilon_{i70}\right) \\
\Delta\%X_{i90} &= \%X_{i90} - \%X_{i80} = \left(\beta_{02}-\beta_{01}\right) + \left(\beta_{12}-\beta_{11}\right)\left(1/d_i\right) + \left(\varepsilon_{i90}-\varepsilon_{i80}\right) \\
\Delta\%X_{i00} &= \%X_{i00} - \%X_{i90} = \left(\beta_{03}-\beta_{02}\right) + \left(\beta_{13}-\beta_{12}\right)\left(1/d_i\right) + \left(\varepsilon_{i00}-\varepsilon_{970}\right)
\end{aligned} \tag{2}
$$

This implies distinct coefficients on $\left(1/d_i\right)$ for each of the three differences. We can employ dummy variables $D_{i80}, D_{i90}, D_{i00}$ that indicates the terminal year of each difference, define $\Delta\beta_{kt} = (\beta_{kt} - \beta_{kt-1})$ and subsume these equations in a common model:

$$
\begin{aligned}
\Delta\%X_{it} = {} & \Delta\beta_{01}D_{80t} + \Delta\beta_{02}D_{90t} + \Delta\beta_{03}D_{00t} \\
& + \Delta\beta_{11}D_{80t}\left(1/d_i\right) + \Delta\beta_{12}D_{90t}\left(1/d_i\right) + \Delta\beta_{13}D_{00t}\left(1/d_i\right) + \eta_{it}
\end{aligned} \tag{3}
$$

where we assume, for ordinary least squares estimation of the $\Delta\beta_{kt}$ parameters, that $E\left[\varepsilon_{it} - \varepsilon_{it-1}\right]$=0 and $E\left[\left(\varepsilon_{it} - \varepsilon_{it-1}\right)^2\right] = \sigma^2$ for all i and t, and $E\left[\left(\varepsilon_{it} - \varepsilon_{it-1}\right)\left(\varepsilon_{js} - \varepsilon_{js-1}\right)\right] = 0$ for all $i \neq j$ and $t \neq s$.

This simple "differences" specification allows us to estimate separately the changes in the distance coefficients over the three intervals between census years in our data. For example, if the change in the distance coefficient is positive over any census decade, then the shape of the distance profile is changing over that decade to reflect an increasing relative concentration of group X near the Superfund site, relative to farther away.

We use proportions, rather than counts, to make our dependent variables comparable across census tracts. These proportions are census-tract averages of (0,1) variables that capture whether each individual (or household) in the population has a certain characteristic, X_i. We weight the data for each census tract by the number of individuals (or households, or housing units) in the census tract in the ending year of the census interval. This controls, to some extent, for anticipated heteroskedasticity across large- and small-population tracts.[6,7]

When analyzed in terms of differences in the levels of $\%X_{it}$ over each of three decades, the data for each of our four Superfund localities constitute panels with three time-series observations per census tract. Models with fixed or random effects are often indicated when panel data are available, since these models are so valuable for controlling for unobserved sources of heterogeneity across groups (where the groups, in this application, are census tracts). However, models with tract-level fixed effects cannot estimate the effects of variables that are constant over time within each cross-sectional group. Our key variable, distance of the census tract from the Superfund site, is such a variable. Fixed effects for each census tract are therefore inappropriate in this model.

Nevertheless, there are still a number of stochastic considerations relevant to cross-section/time-series data. Our number of time-series observations for each group is very small and the number of groups is large relative to the overall numbers of observations. Thus we are limited to specifications that employ time-wise fixed effects (dummy variables for each census year whose coefficients will absorb any systematic area-wide shifts over time in each dependent variable), heteroscedasticity across census tracts, and a common AR(1) error process shared by all census tracts. This appears to be the greatest level of generality for the error structure permitted by the quantities of data we have available.[8,9]

Differenced Model with Other Distances. We next generalize our basic "differenced model with time-wise heterogeneity" to control for the reciprocals of the distances to a number of other geographic features that may represent local amenities or disamenities, including (among other site-specific features) the primary regional central business district, the nearest retail center, the nearest airport(s), the nearest railroad, the nearest major road, and the nearest transit terminal. We denote these other distance variables generically as $\left(1/d_{ij}\right)$, where the j

subscript denotes each of these other features. We allow for analogous discrete changes over time in the measured effects of proximity to these other features, $\left(1/d_{ij}\right)$, resulting in a set of additional coefficients in our models, ($\gamma_{k0}, \gamma_{k1}, k = 1,..., K_j$), depending upon which distance variables are relevant for a particular locality.[10]

Equation (3) can thus be generalized to achieve the specification that produces the empirical results we discuss in this paper:

$$\begin{aligned}\Delta\% X_{it} &= \Delta\beta_{01}D_{i80} + \Delta\beta_{02}D_{i90} + \Delta\beta_{03}D_{i00} \\ &+ \Delta\beta_{11}D_{i80}\left(1/d_i\right) + \Delta\beta_{12}D_{i90}\left(1/d_i\right) + \Delta\beta_{13}D_{i00}\left(1/d_i\right) \\ &+ \sum_{k=1}^{K}\left[\Delta\delta_{k11}D_{i80}\left(1/d_{ik}\right) + \Delta\delta_{k12}D_{i90}\left(1/d_{ik}\right) + \Delta\delta_{k13}D_{i00}\left(1/d_{ik}\right)\right] + \eta_{it}\end{aligned} \tag{4}$$

III. Data

Our goal in this analysis is to look for evidence of the out-migration of more-sensitive groups from areas closest to significant sources of environmental contamination, as well as in-migration of less-sensitive groups. If this evidence is present in the data, it should be most apparent for Superfund sites with high Hazard Ranking System (HRS) scores. We are constrained to working with Census data aggregated to the tract level. To have enough observations (tracts) within the relevant geographical area where people are likely to perceive at least some risk from a Superfund site, we require high population densities, so that the tracts themselves are correspondingly small in area. It would also be desirable to have Superfund sites representing environmental threats that became known rather suddenly, so that there is a clear point in time when an impetus for migration can be known to have emerged. Finally, it would be important to have the threat removed, by cleanup, so that reverse migration may have begun to take place within the time-frame of our census-based sample.

Despite the roughly 1400 sites on the National Priorities List (NPL) and the hundreds of sites that have undergone various degrees of remediation, it is difficult to find sites that satisfy all our criteria, so we have selected four that satisfy at least some of them: the Old Bethpage Landfill Site on Long Island, the Tacoma Commencement Bay/Asarco Smelter site, the Dallas RSR lead smelter site, and Love Canal near Niagara Falls. See Appendix Table A1 for brief summaries of each of these Superfund sites.

The Old Bethpage Landfill site was proposed for listing on the NPL in 1981, and construction for the entire site was complete in 1993. Of the four sites analyzed in this paper, it is likely that the Old Bethpage Landfill site will provide the clearest opportunity for finding evidence of migration patterns, and their reversal, across the 31 years spanned by the available data. We expect to see the initial out-migration of sensitive populations during the 1970s. By the time the site was listed in 1981, it was no surprise to the local population that the landfill represented a significant environmental risk.

While there are several different project areas in the overall Tacoma Superfund site in our study, we focus on Project Areas 1 and 2, and treat the site of the former ASARCO smelter as the base location of the site. The site was proposed for listing in 1982 and there was considerable awareness before that, although cleanup was not expected to be complete until 2003-05. Thus we again expect to see the initial out-migration of sensitive populations during the 1970s.

At the Dallas RSR site, lead contamination of the soil at the site and in the surrounding community is reported to have been a concern only since the early 1980s. The site was not proposed for listing until 1993. Removal activities were apparently completed in 2002.[11] We thus expect that measurable out-migration of sensitive groups at this site should be apparent only in the decade of the 1980s, rather than earlier. Since cleanup was not complete by 2000, reverse migration may not be apparent by the end of our sample period.

For the Love Canal site (the "poster child" site that precipitated the Superfund program), we omit from the analysis the census tract that contained the site itself, since in 1978 and 1980, two "environmental emergencies" were issued for the area and about 950 families were evacuated from a ten-square-block area around the landfill. These mandated evacuations do not reflect the independent choices of residents in that neighborhood. The site was proposed for listing on the NPL in 1981 and clean-up was not declared to be complete until March of 2004. For other nearby census tracts which were not subject to mandatory evacuation, we would thus expect to see out-migration of sensitive populations beginning to occur at the very end of the 1970s and into the 1980s. Since the official cleanup completion is after our 1970-2000 sample window, however, we do not necessarily expect to see much reverse migration by 2000, although reverse migration to the nearby tracts in our sample might have begun sooner.

Census tract sociodemographics. The data for this study come from the Neighborhood Change Database (NCDB), provided by GeoLytics, Inc. The NCDB normalizes US census data from the 1970, 1980, 1990 and 2000 censuses to the same spatial extent as tracts used in the 2000 census. Data from all four census years for many variables can thus be compared, since the effective geographic boundaries for census tracts remain constant (to the extent possible) throughout the time span.[12] Except for average house value, which remains denominated in dollars, absolute frequencies in the census data are converted into proportions.[13]

For incomes and rental rates, reported in current dollars and in vastly different sets of brackets over the four different census years, it is necessary to devise a way to make the data comparable across census years. To distinguish changes in incomes over time (in tracts close to the Superfund site versus farther away) we measure the proportion of household incomes in each tract that exceed the area-wide median (where the "area" is defined as tracts within our 12-kilometer radius). For each tract, we first construct the income distribution, defined in terms of the proportions of households falling within each income bracket. However, bracket definitions change drastically between census years due to inflation. For each census year, then, we identify the one boundary, between that year's income brackets, that most closely approximates the area-wide median value for each variable. We take this area-wide near-median income bracket boundary and, for each tract within the area, determine what proportion of households have incomes greater than this boundary.[14]

Our initial data construction process leads to four site-specific datasets with all relevant dependent variables generated as proportions (except for average house value) for the four censuses, normalized to the 2000 census tract boundary definitions.

Distance data. Our most important explanatory variable is the distance from each census tract to the Superfund site. This distance serves as a proxy for perceived exposure to any hazards from the site. Centroids are identified for each tract to serve as an approximate point of measurement from the tract to the Superfund site. All distance data are measured in kilometers.[15] Also necessary are variables that measure the distance from each tract to other significant geographic features. These features may be either specific points, such as a specific airport, or the nearest member of a class of features, such as the local transit terminals.

While features such as a central business district, roads, transit terminals, railroads, retail outlets and an airport are common to all four sites, several site-specific distances are calculated as well. We control carefully for distances from each tract to other local amenities and disamenities so as to avoid attributing all economic and demographic variation solely to the distance from the tract to the Superfund site (and therefore implicitly to the perceived risks from the site), when in fact some of this variation is due to the tract's distance from other features.

We merge distance data with our sociodemographic, economic, and residential mobility data, based on year and census tract, to obtain four site-specific datasets containing all desired information for each of the four sites and four census years. Summary statistics of the sociodemographic and housing market data are contained in Appendix Table A2. Summary statistics for the distance data can be found in Appendix Table A3.

IV. Results and Interpretation.

Comprehensive numeric estimates for all of the regression parameters for all 22 models for all four sites are available from the authors. It is necessary to distill from this daunting amount of information the central findings from this study. For each dependent variable, these central findings pertain to the three key coefficients–$\Delta\beta_{11}$, $\Delta\beta_{12}$, and $\Delta\beta_{13}$–which convey the shifts in the slopes of the distance profiles over each of the three decades bounded by the four censuses. In Table 1, for Old Bethpage Landfill on Long Island, we provide one complete set of regression results. The dependent variable in this example is the proportion of young children aged less than six years.[16]

The focus of this study is the sign and statistical significance of the shifts in concentration, near the site versus farther away, compared across our four different Superfund localities. The most compact symbol-based summary of this information, for all 22 variables and all four Superfund sites, is provided in Table 2. The results for $\Delta\beta_{11}$, $\Delta\beta_{12}$, and $\Delta\beta_{13}$ are coded in triples of characters corresponding to each of the three decades in this study. The symbol "/" indicates a statistically significant and positive estimate for a slope differential on our dependent variable, representing a growth in that decade of the concentration of the group in question nearer the Superfund site, relative to farther away. The "\" symbol indicates a statistically significant negative estimate of the slope differential (a decline in relative concentration), while the “-” symbol indicates no statistically discernible change in the distance profile over the decade in question. Slope profiles with an “°” signify statistically significant movements that are consistent with hypotheses derived from basic intuition about sensitive populations.

Trends during the decade of recognition/listing. We first explore the data for any changes in the relative concentrations of different types of households relative to the location of the Superfund site, across time, as the site is listed and remediation activities are initiated. We are looking for traces of similarities in movements across our four sites. We see the greatest evidence of similarities in the 1970’s for Old Bethpage Landfill and the Tacoma Asarco/Commencement Bay area. For these two sites, our separate models both suggest declining concentrations of children under six, married couples with children, rental rates above the area-wide median, and incomes above the area-wide median. Likewise, both suggest increasing concentrations of seniors, married couples without children, non-family households, and people residing in the same house five years previously. (Nearer the Superfund sites, people were relatively more likely to be stuck in the same dwelling. Housing units may be rendered more difficult to sell by their greater perceived environmental risks.[17]) All of these similar trends are statistically significant at both locations.

Love Canal matches several of these trends, but they are present in the decade of the 1980’s rather than the 1970’s. As for both the Old Bethpage and Tacoma sites in the 1970s, Love Canal in the 1980’s exhibits declining proportions of children under six and declining shares of rental rates above the area-wide median. Love Canal in the 1980’s also matches Tacoma in the 1970s with evidence of declining shares of children between six and seventeen, and matches Old Bethpage in the 1970s in terms of increasing shares of adults and female-headed households without children. Unlike Bethpage and Tacoma in the 1970s, however, Love Canal tracts near the site in the 1980’s exhibit declining shares of people who lived in a different house in the same county five years previously. (People were less likely to move into the vicinity of the Love Canal site from somewhere else in the county at these two sites. This may be because county residents are more likely than outsiders to be aware of the area's environmental problems.) This pattern is also apparent for the Dallas RSR site in the 1970s.

Evidence of reversals, with remediation effort. We assume that neighborhood residents first experience an increase in perceived risk as the Superfund site is identified and listed, and then a decrease in perceived risk as the remediation process is initiated and finally completed. Thus we expect to see both an ebb and a flow in our different measures of neighborhood characteristics.[18] Table 3 reveals evidence of this "rebound" pattern. In this table, we highlight instances where the initial movement is consistent with our intuition. Plausible rebound effects for specific demographic variables at each site are emphasized by connection between the movement symbols of Table 2. The symbol " _____/ " , for example, indicates that the variable in question declined in relative concentration near the site in one decade and then increased in relative concentration in the following decade. Similarly, a " __ – __/ " symbol indicates a decline in relative concentration in the first decade (1970's), no change in the second (1980's) and a rebound effect in the third (1990's). As one might expect, a " /‾‾‾‾‾\ " symbol shows an increase in relative concentration in the first decade and a decrease in the next.

For Bethpage during the 1970s and 1980s, and for Love Canal during the 1980s and 1990s, children under six first move away from the site (i.e. decline in proportion nearer the site versus farther away), then begin to return to the neighborhoods nearest the site as the cleanup process begins. The inverse pattern for adults appears around Bethpage in the 1970s and 1980s.

Bethpage exhibits a decrease, then an increase, in the proportion of married couples with children, and the opposite pattern for married couples without children. The latter pattern is also present at Tacoma. At Bethpage in the 1970s and 1980s, and at Dallas and Love Canal in the

1980s and 1990s, the proportion of female-headed households without children first increases, then decreases. Many of these individuals may be older widows who may feel tied to their homes, despite the environmental problems in the neighborhood.

At Bethpage, the proportions of rental rates and incomes higher than the area-wide median, near the site as opposed to farther away, decline significantly in the 1970s. Rents continue to decline in the 1980s, but both rents and incomes increase again in the decade of the 1990s, suggesting some recovery of housing markets and the socioeconomic status of residents.

Contrary to the predictions of much of the environmental justice/equity literature, the statistically significant migration trends in the Bethpage case suggest that whites moved into the area near the landfill during the period of initial recognition of the hazard (the 1970s), while African-Americans were moving away. There has been no reversal of this initial-decade shift.

In the Tacoma case, however, whites declined in relative concentration near the site in the 1970s, as did Hispanics, but African Americans moved closer. By 2000, there had been no statistically significant reversal of the “white flight” of the 70s, although African-Americans declined in relative concentration and Hispanics returned.

Housing Prices/Rental Rates. Average house values near the site show no significant changes, relative to house values farther away, either at the Bethpage site or at the Dallas site. This finding is notable because many papers in the hedonic literature rely explicitly upon changes in house values over time to capture the welfare effects of perceived environmental hazards. Census house values are self-reported, but Kiel and Zabel (1999) observe that self-reported house values, on average, are fairly accurate. Even at Love Canal, where we drop the tract containing the site itself (because of mandated evacuations), we observe no statistically significant decline in relative housing prices nearer the site, but a statistically significant increase as the site is cleaned up (during the 1990s). Only around the Tacoma site are there significant relative spatial changes across decades in house values. Around the Tacoma site during the 1970s, families with children (and the proportions of children under six, and between six and seventeen) are declining, the proportion of whites is decreasing, and rental rates and incomes above the median are falling. However, couples without children, non-family households, seniors, and people who have lived in the same house for more than five years are increasing. Despite these trends, average house values near the site, relative to farther away, increase during the 1970 and 1980s, even as the hazard is recognized and the Superfund site is listed. Only in the 1990s do house values register a statistically significant decline.

Explicit Mobility Variables. There are a number of plausible patterns in our five explicit mobility variables. During the 1970s at Bethpage and Tacoma, and during the 1980s at Love Canal, when the environmental problems were becoming evident, people may have been finding it more difficult to sell their houses at typical intervals. In census tracts nearest the site, relative to farther away, we see increases in the proportion of people still in the same house that they occupied five years earlier.

People residing in a “different house, but in the same county five years earlier” would have moved to their current tract within the last five years. The problems in the vicinity of the Dallas site in the 1970s or the Love Canal site in the 1980s were probably much more evident to locals than to persons migrating in from farther away. It is plausible that relatively fewer people would be moving close to these two sites from somewhere else in the same county, and relatively more people would be moving into tracts at greater distances from each site.

During the 1980s, when the Bethpage site was listed on the NPL, the proportion of vacant dwellings in census tracts closer to the Bethpage site increased relative to the proportion in tracts farther away. The proportion of renter-occupied units near the site increased relative to the proportion farther away during the 1980s. The proportion of owner-occupied units near the site, relative to farther away, fell during the 1970s, but there were no statistically significant changes in the 1980s or the 1990s. The significant relative decline in owner-occupation around the Tacoma site took place during the 1980s.

There are also some interesting explicit mobility patterns in the census tracts around the Love Canal site. The site was both recognized and listed in the early 1980s. During the 80s, we see a suggestion that people are not able to sell their houses and to move as readily as they might be expected to, since the proportion of people in the same house as they were five years earlier increases near the site relative to farther away. This stickiness in the market appears to be resolved during the 1990s, with the cleanup. At Love Canal, we also see that significantly fewer people move into the nearby tracts from elsewhere in the same county during the 1980s, compared to the rates at which they move into more distant tracts in the same area. This reluctance for people in the county to relocate near to Love Canal is also reversed in the1990s.

Oddly, however, while the proportion of vacant units near the Love Canal site, relative to farther away, is increasing during the 1970s, it declines during the 1980s. During the 1980s, there are also statistically significant decreases in the proportion of renter-occupied units and increases in the proportion of owner-occupied housing, relative to what is happening in tracts that are farther removed from the site. Since the proportion of rental rates above the area-wide median near Love Canal (relative to farther away) is falling in the 1980s, however, it is possible that the nearby rental market has been decimated by the flight of renters and that owners have been forced to occupy these housing units themselves. Demand for rental units near Love Canal, relative to farther away, appears to begin to recover in the 1990s.

V. Conclusions

By looking where it is most likely to be found, we have uncovered ample systematic and plausible evidence of environmental migration, at the local level, precipitated by the recognition of environmental hazards. Our empirical results for the Old Bethpage Landfill site are the clearest. Of the 22 sociodemographic variables we consider, ten show statistically significant evidence of changes near the site that differ from those in tracts that lie farther away and also match similar tendencies at one or more other sites among the four we study. Specifically, the groups that tend to decline (relatively) near the site are children under six, married couples with children, rental rates above the area-wide median, incomes above the area-wide median, and people residing in a different house but in the same county five years earlier. The groups that tend to increase (relatively) near the site are seniors, married couples without children, female-headed households without children, non-family households, and people residing in the same house five years previously.

Similar migration patterns may occur in the vicinity of many other significant environmental hazards. However, the population densities in many such localities will be insufficient to support a large enough number of census tracts, close enough to the site, for this type of empirical analysis to be undertaken. In Cameron and Crawford (2004) for example, where most of the Superfund sites in the analysis had lower Hazard Ranking System scores, it proved more difficult to find unambiguous statistical evidence of changes such as these.

Traditional hedonic property value studies of the effects on housing prices of proximity to environmental threats sometimes use neighborhood sociodemographic characteristics as exogenous control variables. Often, however, these studies use sociodemographic characteristics in just one baseline year. They typically fail to acknowledge sufficiently that the levels of these characteristics are jointly endogenous with the housing prices being modeled. We estimate reduced-form specifications for a wide variety of these endogenous characteristics. Any model of changes over time in housing prices (such as before and after the recognition of an environmental threat) needs to control for changes over time in sociodemographic characteristics of the neighborhood. However, not only housing prices, but also these sociodemographic characteristics, can be affected by proximity to known environmental hazards.[19]

The question of whether depressed housing prices recover upon the removal of an environmental disamenity has intrigued a number of researchers, including Dale, et al. (1999), Hite, et al. (2001), McCluskey and Rausser (2003), and Messer, et al. (2004). The empirical evidence in these studies is mixed. Of our four cases, the Old Bethpage Landfill offers the best prospects for identifying out-migration and reverse migration, relative to the location of the site, over the sample period. NPL listing was proposed in 1981 and cleanup construction completed in 1993.

Of these ten types of migration, statistically significant reverse migration begins to appear (within the sample window) for the Old Bethpage Landfill area in seven cases. These reversals occur for children under six, married couples with children, married couples without children, female-headed households without children, non-family households, rental rates above the area-wide median, and incomes above the area-wide median. The results are somewhat less clear-cut for our other three sites, where cleanup was not complete by the end of our sample window.

What do these results mean for empirical efforts to quantify the social costs of environmental contamination (or the social benefits of cleanup)? We need to think more carefully about the dynamics of readjustment to equilibrium. Studies that have failed to find that housing prices rebound to the same levels that prevailed prior to cleanup may be assuming, implicitly, that sociodemographic characteristics of the affected neighborhoods were unaffected by events surrounding the discovery and remediation of an environmental hazard (or at least that these characteristics are exogenous). If households were immobile and the environmental risk was transitory, we might expect that restoration of the status quo ante was a possibility (if current and prospective residents believed the cleanup to be effective and complete). However, if the character of the neighborhood is fundamentally changed by these events, and reverse migration is not instantaneous, we would expect to see prolonged effects upon housing prices, perhaps even far beyond the completion of cleanup. With relocation, utility losses will be less than without relocation, but moving costs can substantially limit households' abilities to continuously adjust their location in response to variations in perceived environmental threats.[20]

Researchers have already begun to explore the general equilibrium consequences of changes in environmental quality and to recognize the need to attend to issues of locational equilibrium. This study strongly supports the maintained hypothesis, in that literature, that households do indeed relocate in response to environmental threats.

Table 1: Example of complete results for one regression model (proportion aged less than 6 years, Old Bethpage Landfill)
Cross-sectional time-series FGLS, heteroscedastic, common AR(1) coefficient for all tracts (-0.3909)
(n = 134 tracts, T= 3 changes between censuses)

Decade:	1970-80		1980-90		1990-00		p-value[a]	Symbolic summary		
Distance from:	Coef.	Asy t-ratio	Coef.	Asy t-ratio	Coef.	Asy t-ratio				
Superfund site	-0.2467	(14.03)***	0.1470	(7.98)***	0.01764	(0.89)		\°	/	-
Airport	0.000952	(12.12)***	0.0008875	(11.04)***	0.0008644	(11.49)***	0.000			
Bridge to Manhattan	-2.275	(0.94)	19.23	(7.79)***	-8.798	(3.63)***	0.000			
Northwest shore, Long Island	0.2988	(7.41)***	-0.003875	(0.09)	-0.03949	(0.99)	0.000			
Southeast shore, Long Island	0.05143	(3.06)***	-0.01805	(1.06)	-0.002858	(0.17)	0.020			
Major road	0.001197	(4.62)***	-0.0001760	(0.66)	-0.0002607	(0.99)	0.000			
Retail center	-0.003937	(0.25)	-0.002762	(0.17)	0.03625	(2.23)**	0.128			
Railway line	0.005456	(4.08)***	-0.001415	(1.06)	-0.001079	(0.87)	0.0003			
Transit terminal	0.1720	(3.06)***	-0.08108	(1.45)	-0.2286	(4.45)***	0.000			
Landmark	-0.000472	(0.89)	-0.0000816	(0.16)	0.0004449	(0.87)	0.604			
Constant[b]	-0.5457	(11.29)***	0.3570	(4.39)***	0.8615	(13.73)***				
Maximized Log L			-604.3596							

[a] P-value for a test of the hypothesis that all three coefficients for this distance variable are jointly zero.
[b] Constant is estimated as a baseline for 1970-80 and shifts in 1980-90 and 1990-00; other coefficients are $\Delta\beta_{11}$, $\Delta\beta_{12}$, and $\Delta\beta_{13}$
° signifies that estimated slope in the 1970-80 period is consistent with prior intuition: children ages less than six tend to be moved away from the neighborhood of the Superfund site in the first decade. In contrast, they return to the area in the 1980-90 decade.

Table 2: Summary of changes in distance profiles between census years[a]

Superfund site:	Bethpage[b]			Tacoma[b]			Dallas[b]			Love Canal[b]		
NPL listing date:	9/8/1983			9/8/1983			9/29/1995			9/1/1983		
Dependent variable[c]	**70's**	80's	90's	**70's**	80's	90's	70's	**80's**	90's	70's	**80's**	90's
Children under 6	\°	/	-	\°	-	-	-	-	-	/	\°	/
Children 6 to 17	-	-	-	\°	-	-	/	\°	/	/	\°	-
Adults	/°	\	-	-	-	-	-	-	-	\	/°	-
Seniors	/°	/	-	/°	-	\	-	-	-	/	-	-
Married couples with children	\°	/	/	\°	-	-	/	-	-	/	-	-
Male-headed household with children	-	-	-	-	-	\	-	-	-	-	\°	-
Female-headed with children	-	-	-	-	/	-	/	\°	/	-	-	-
Married couples without children	/°	\	\	/°	\	/	\	/°	-	-	\	-
Male-headed household without children	-	-	-	-	-	-	\	-	-	-	-	-
Female-headed household without children	/°	\	-	-	-	/	-	/°	\	\	/°	\
Non-family households	/°	/	\	/°	-	-	-	/°	-	-	-	-
White	/	-	-	\°	-	-	/	-	-	-	-	-
African-American	\	-	-	/°	-	\	-	-	-	-	-	-
Hispanic	-	-	-	\	-	/	-	-	-	-	-	-
Average house value	-	-	-	/	/	\	-	-	-	-	-	/
Rental rates above area-wide median	\°	\	/	\°	-	-	-	-	\	/	\°	-
Incomes above area-wide median	\°	-	/	\°	-	-	-	-	-	-	-	-
Same house 5 years yrs ago	/°	-	-	/°	-	-	-	\	-	\	/°	\
Different house, same county 5 yrs ago	-	-	-	-	/	\	\	-	-	/	\°	/
Vacant housing units	-	/	-	-	-	-	-	-	-	/	\	-
Renter-occupied housing units	-	/	-	-	-	-	-	-	-	-	\	/
Owner-occupied housing units	\°	-	-	-	\	-	-	-	-	-	/	-

[a]key: \ = declining in relative concentration near site; / = increasing in relative concentration; - = insignificant

[b]bold-face = expected decade of response: some prior knowledge was available in the decade prior to listing for all sites except Love Canal

[c]all dependent variables are proportions, except for average house value, which is denominated in dollars

° indicates that the change in relative concentration near the site, in the decade of expected response, is consistent with hypotheses derived from basic intuition

Table 3: Evidence of "Rebound" Associated with Cleanup[a]

Superfund site:	Bethpage[b]			Tacoma[b]			Dallas[b]			Love Canal[b]		
NPL listing date:	9/8/1983			9/8/1983			9/29/1995			9/1/1983		
Dependent variable[c]	**70's**	80's	90's	**70's**	80's	90's	70's	**80's**	90's	70's	**80's**	90's
Children under 6	___	___/	-	\	-	-	-	-	-	/	___	___/
Children 6 to 17	-	-	-	\	-	-	/	___	___/	/	\	-
Adults	/‾‾‾	‾‾‾\	-	-	-	-	-	-	-	\	/	-
Seniors	/	/	-	/‾‾	-	‾‾\	-	-	-	/	-	-
Married couples with children	___	___/	/	\	-	-	/	-	-	/	-	-
Male-headed household with children				-	-	\	-	-	-	-	\	-
Female-headed with children	-	-	-	-	/	-	/	/‾‾‾	‾‾‾\	-	-	-
Married couples without children	/‾‾‾	‾‾‾\	\	/‾‾‾	‾‾‾\	/	\	/	-	-	\	-
Male-headed household without children	-	-	-	-	-	-	\	-	-	-	-	-
Female-headed household without children	/‾‾‾	‾‾‾\	-	-	-	/	-	/‾‾‾	‾‾‾\	\	/‾‾‾	‾‾‾\
Non-family households	/	/‾‾‾	‾‾‾\	/	-	-	-	/	-	-	-	-
White	/	-	-	\	-	-	/	-	-	-	-	-
African-American	\	-	-	/‾‾	-	‾‾\	-	-	-	-	-	-
Hispanic	-	-	-	__	-	__/	-	-	-	-	-	-
Average house value	-	-	-	/	/	\	-	-	-	-	-	/
Rental rates above area-wide median	\	___	___/	\	-	-	-	-	\	/	\	-
Incomes above area-wide median	__	-	__/	\	-	-	-	-	-	-	-	-
Same house 5 years yrs ago	/	-	-	/	-	-	-	\	-	\	/‾‾‾	‾‾‾\
Different house, same county 5 yrs ago	-	-	-	-	/‾‾‾	‾‾‾\	\	-	-	/	___	___/
Vacant housing units	-	/	-	-	-	-	-	-	-	/	\	-
Renter-occupied housing units	-	/	-	-	-	-	-	-	-	-	___	___/
Owner-occupied housing units	\	-	-	-	\	-	-	-	-	-	/	-

[a]key: \ = declining in relative concentration near site; / = increasing in relative concentration; - = insignificant

[b]bold-face = expected decade of response: some prior knowledge was available in the decade prior to listing for all sites except Love Canal

[c]all dependent variables are proportions, except for average house value, which is denominated in dollars

Appendix

Table A1 – Synopses of Superfund Sites used in Study

	Bethpage Landfill	**Tacoma ASARCO**	**Dallas RSR**	**Love Canal**
HRS Score	58.83	42.20	50.00	52.23
NPL Listing (initial, final)	1981, 1983	1982, 1983	1993, 1995	1981 , 1983
Dates Active	1957-1978	1890-1985	1934-1984	1890-1952
Primary Use	Disposal of incinerator wastes	Copper smelting	Lead smelting	Disposal of chemical wastes
Health Risk	Groundwater contamination with volatile organic compounds.	Release of arsenic, cadmium, copper, lead and zinc into the soil, groundwater, air and bay.	Lead contamination of soil	Groundwater and soil contamination of chemical residues
Remediation	Began in 1982 with a methane gas and leachate collection system along with a clay cap. Construction for the entire site was complete in 1993.	Smelter demolished during 1993-94. Remedial action at ASARCO site began in 1998. Expected cleanup for Project Areas #1 and #2: 2003-2005.	A series of cleanup measures were applied during the 1980's after the site was closed (Dale, et al. (1999)). In 1984, lead-contaminated soil was removed from yards within a half-mile of the smelter. Significant remediation in 1994 and 1995. Remediation complete in 2002.	In 1978 and 80, two "environmental emergencies" we declared, evacuating around 950 families from a 10 block radius of the Superfund Site. Cleanup of the site was not declared complete until March 2004.

Table A2 – Summary statistics for census tract proportions

	Bethpage		Tacoma		Dallas		Love Canal	
Dependent variable[a]	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
Children under 6	0.2885	0.0730	0.0741	0.0207	0.0842	0.0317	0.0705	0.0194
Children 6 to 17	0.0784	0.0209	0.2018	0.0596	0.1970	0.0720	0.2085	0.0556
Adults	0.5361	0.0646	0.6076	0.0578	0.6235	0.0919	0.5883	0.0422
Seniors	0.0970	0.0428	0.1158	0.0667	0.0950	0.0599	0.1328	0.0600
Married couples with children	0.4643	0.1186	0.3905	0.1071	0.3716	0.1323	0.3855	0.1209
Male-headed household with children	0.0098	0.0091	0.0231	0.0231	0.0232	0.0209	0.0191	0.0289
Female-headed with children	0.0476	0.0391	0.0989	0.0621	0.1170	0.0914	0.0972	0.0892
Married couples without children	0.3934	0.0918	0.4188	0.0878	0.3574	0.1344	0.4060	0.0903
Male-headed household without children	0.0234	0.0149	0.0200	0.0158	0.0415	0.0375	0.0259	0.0304
Female-headed household without children	0.0614	0.0342	0.0486	0.0363	0.0893	0.0669	0.0662	0.0366
Non-family households	0.1660	0.1138	0.6397	1.2172	0.6479	0.8271	0.4003	0.2970
White	0.9012	0.1951	0.8642	0.1324	0.6070	0.3357	0.9058	0.1797
African-American	0.0662	0.1839	0.0700	0.0908	0.2401	0.3340	0.0667	0.1550
Hispanic	0.0421	0.0483	0.0292	0.0264	0.2485	0.2485	0.0109	0.0108
Average house value	138,648	149,697	92,668	73,826	78,158	112,694	49,461	30,559
Rental rates above area-wide median	0.7006	0.2317	0.5715	0.2303	0.4464	0.2533	0.4756	0.2364
Incomes above area-wide median	0.5743	0.1333	0.5258	0.1759	0.4342	0.1929	0.4737	0.1583
People residing in the same house 5+ years	0.6851	0.1162	0.4526	0.0985	0.4346	0.1491	0.6368	0.0944
People residing in a different house, same county 5+ years	0.1073	0.0475	0.2877	0.0705	0.3399	0.0964	0.2570	0.0743
Vacant housing units	0.0178	0.0164	0.0744	0.0501	0.0949	0.0725	0.0563	0.0560
Renter-occupied housing units	0.1378	0.1064	0.3275	0.1772	0.4730	0.2012	0.3007	0.1764
Owner-occupied housing units	0.8711	0.0997	0.5992	0.1951	0.4342	0.2347	0.6430	0.2040

[a]all dependent variable data are census tract proportions, except average house value, which is denominated in dollars

Table A3: Summary statistics for raw distance data (measured in kilometers)								
	Bethpage		Tacoma		Dallas		Love Canal	
	(tracts = 134)		(tracts = 45)		(tracts = 142)		(tracts =46)	
Key Distance variable	*Mean*	*Std. Dev.*	*Mean*	*Std.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
Distance to Superfund site	8.10609	2.5322	7.930	2.8569	8.352	2.738	7.317	2.962
Distances to other amenities/disamenities[a]								
Central business district 1[b]	61.32056	6.3244	6.631	4.230	10.94	6.190	8.046	5.277
Central business district 2[b]			44.34	9.312			21.18	6.504
Transit terminals	9.00848	2.62739	5.223	2.766	5.130	2.405	8.657	6.030
Retail outlets	6.19086	2.36489	7.217	4.409	7.660	2.823	5.605	2.237
Railroads	1.60149	1.14864	2.345	2.497	1.215	1.021	1.252	1.189
Major roads	0.32503	0.24105	2.514	2.174	1.292	0.9625	3.157	1.951
Airport 1[c]	7.44461	3.33134	23.36	4.754	16.21	6.158	6.741	3.033
Airport 2[c]							22.33	7.180
North shore Long Island	13.01111	4.89452						
South shore Long Island	8.22691	5.3406						
Major landmarks	3.32163	1.75318						
Major bodies of water			6.024	3.918	22.52	4.581	1.525	1.088
Military bases			11.88	4.682	12.68	4.958		
Boeing airfield			31.78	4.645				
Mainland access points[d]			18.41	4.974				
Colleges			10.61	3.481	4.194	1.935	5.947	2.556
Golf courses and country			2.966	2.785	2.535	1.306	2.338	1.445
McChord Air Force base			12.50	5.146				
Municipal airports			8.717	4.072	6.129	2.930	30.42	7.091
Non-mainland tracts[e]			5.815	3.759				
Parks			1.153	1.352	0.5901	0.4270	1.057	0.7803
Shoreline			4.890	4.299				
Hospitals					5.875	3.214	4.183	3.003
Rivers					1.058	0.7784	7.122	4.231
Filtration plant					9.750	3.910		
Sewage treatment plant					8.278	3.523		

[a]distances used as controls differ between sites due to availability of data and conditions surrounding the Superfund site in question.
[b]central business districts: *Bethpage* 1 = Manhattan; *Tacoma* 1 = Tacoma, 2 = Seattle; *Dallas* 1 = Dallas; *Love Canal* 1 = Niagara Falls, (2) = Buffalo.
[c]airports: *Bethpage* Republic Airport; *Tacoma* Sea-Tact; *Dallas* 1 = Dallas/Fort Worth; *Love Canal* 1 = Niagara Falls, 2 = Buffalo.
[d]points of access to mainland from islands (i.e., bridges, ferries);
[e]dummy variable for island tracts.

Table A4: Key coefficients, all regressions, Old Bethpage Landfill; intercensal changes in slopes on reciprocal of distance from census tract to Superfund site[a] (n = 134 tracts)

Dependent variable[a] *Interval:*	$\Delta\beta_{11}$ *1970-1980*	$\Delta\beta_{12}$ *1980-1990*	$\Delta\beta_{13}$ *1990-2000*
Children under 6	-0.2467	0.1470	0.01764
	(14.03)***	(7.98)***	(0.89)
Children 6 to 17	-0.008679	0.006454	-0.01226
	(0.52)	(0.37)	(0.66)
Adults	0.1285	-0.2272	-0.02801
	(2.47)**	(4.18)***	(0.48)
Seniors	0.1142	0.06523	0.01370
	(4.04)***	(2.20)**	(0.43)
Married couples with children	-0.4902	0.1490	0.1171
	(17.21)***	(5.00)***	(3.66)***
Male-headed household with children	-0.003586	-0.003529	-0.01690
	(0.30)	(0.29)	(1.29)
Female-headed with children	0.01845	-0.01075	-0.0001378
	(1.05)	(0.59)	(0.01)
Married couples without children	0.3624	-0.06497	-0.1318
	(12.54)***	(2.15)**	(4.05)***
Male-headed household without children	0.008408	-0.003602	-0.009163
	(0.73)	(0.30)	(0.71)
Female-headed household without children	0.07330	-0.07734	0.03814
	(3.47)***	(3.50)***	(1.61)
Non-family households	0.1104	0.1709	-0.2197
	(2.65)***	(3.92)***	(4.73)***
White	0.1523	-0.01589	0.06299
	(2.86)***	(0.29)	(1.07)
African-American	-0.1010	0.01357	-0.01295
	(3.60)***	(0.47)	(0.44)
Hispanic	-0.05092	0.02165	-0.04102
	(1.55)	(0.63)	(1.13)
Average house value	14278.0	34327.6	5461.7
	(0.55)	(1.27)	(0.19)
Rental rates above area-wide median	-0.6470	-1.513	1.679
	(2.87)***	(6.42)***	(6.62)***
Incomes above area-wide median	-0.3301	-0.04812	0.1371
	(6.76)***	(0.94)	(2.49)**
People residing in the same house 5+ years	0.04188	-0.000[c]	-0.000[c]
	(3.97)***	(0.00)[c]	(0.00)[c]
People residing in a different house, same county 5+	-0.004994	0.000[c]	-0.000[c]
	(0.59)	(0.00)[c]	(0.00)[c]
Vacant housing units	-0.01307	0.02612	-0.01793
	(1.28)	(2.45)**	(1.58)
Rental housing units	0.04729	0.1767	-0.08188
	(0.94)	(3.36)***	(1.48)
Owner-occupied housing units	-0.1213	-0.000[c]	0.000[c]
	(7.42)***	(0.00)[c]	(0.00)[c]

[a] Each row corresponds to a different regression, which also controls for distances to other amenities and disamenities. Parameters are estimated by GLS for pooled time-series cross-sectional data, weighted by tract populations and including time fixed effects as well as AR(1) errors.
[b]All dependent variables are census tract proportions, except for average house value, which is denominated in dollars
[c] Essentially zero

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Notes

[1] Some of the more notable contributions since that time have included a meta-analysis of 37 studies conducted by Smith and Huang (1995), progress on the empirical estimates of values for non-marginal changes for air quality by Chattopadhyay (1999), work on identification in hedonic models by Ekeland, et al. (2002) and Ekeland, et al. (2004), and a comprehensive empirical assessment of the effects of air pollution on housing values at the county level, taking advantage of Clean Air Act non-attainment status as an instrument, by Chay and Greenstone (2004).

[2] They use a simulation strategy to illustration the consequences of migration, but note that "…in the absence of information on the extent of migration..." it is difficult to interpret the extent of their simulated measures.

[3] The radius of influence of each superfund site on housing prices is likely to be considerably less than the twelve-kilometer radius over which our data extend.

[4] At issue is the question of whether unobserved heterogeneity across census tracts accounts in part for both the presence of an NPL site and systematically different tract characteristics in 1980, both of which influence property values in 1990. Isolating the ceteris paribus effect on 1990 property values of bestowing an NPL site upon a randomly selected census tract would certainly require recognition of the jointly endogenous character of property values and the presence of an NPL site.

[5] The endogeneity of the locations of Superfund sites, the listing decision, and the pace of the clean-up process have been considered in the environmental justice literature. In our models, technically, the siting decision is regarded as "predetermined." Gayer (2000) has recently examined the endogeneity of the locations of environmental risks and the problem of siting decisions for hazardous facilities.

[6] We discard any tract for which the population is less than 100 in any of the four Census years on the grounds that this appears to provide insufficient precision in calculating the shares of different sociodemographic groups. In these heavily urbanized areas, tracts with fewer than 100 people are probably anomalous in a number of ways.

[7] The difference across census years in the proportion of the population in a particular group, $\Delta\% X_{it}$, is being used as the dependent variable. This difference is bounded by -1 and +1. Fortunately, there are no instances in our data where the value of $\Delta\% X_{it}$ in any year approaches either -1 or +1.

[8] We rely on the xtgls command in Stata8, with weights to reflect the different sizes of each census tract in the ending year of the interval ([aweight=trctpop]), i(trct) t(year) panels(h) and corr(a).

[9] We do not pursue corrections for spatially correlated errors. This decision may have milder consequences in the case of census tract data than in the case of individual hedonic property value data, for example, but we treat the "spatial error" issue as a second-order problem in this paper. This issue has been addressed in hedonic property value models by Kim, et al. (2003). Subsequent research may pursue this aspect of the empirical problem.

[10] In practice, we shift each distance measure by adding 10 meters (0.01 km). This accommodates the occasional zero distance for some of our distance variables in the raw data.

[11] The EPA reports 950 citizens on the site mailing list, and describes constituency interest as "Some very vocal and concerned citizen groups concerned about Environmental Justice issues, distrust of government (all levels), compensation for past exposure, training and jobs, and economic development" (EPA (2004).

[12] There are approximations involved in apportioning earlier census tract data across 2000-year tracts when some tracts have been split over the decades, but these are the best data available.

[13] Appropriate denominators must be used when calculating these proportions (e.g. when constructing variables concerning family structure, we divide by the total number of families rather than the total population of the tract).

[14] For example: for Love Canal in 1970, and area-wide, 53 percent of households had incomes of 10,000 dollars and higher. However, only 37 percent of households had incomes of 12,000 dollars and higher. Therefore, we use the proportion of households in each tract with incomes greater than 10,000 dollars for our "proportion of incomes above area-wide median" variable. Now, suppose that for one low-income tract in Love Canal only 22 percent of households had incomes of 10,000 dollars or higher in 1970. Our variable called "proportion of incomes above area-wide median" would equal 0.22 for that tract.

[15] ArcView GIS 3.2a is used to calculate spatial variables, with data in the relevant UTM-1983 projection; distances are calculated in ESRI's ArcGIS 8.x.

[16] Also just for the Old Bethpage Landfill site, we provide in Appendix Table A4 a summary of the point estimates and standard errors for just the three key coefficients, for all of the dependent variables we consider in our study.

[17] Huang and Palmquist (2001) address questions concerning reservation prices and time on the market in the presence of environmental disamenities.

[18] It would be inappropriate to attribute the decadal trends in our 22 sociodemographic and housing characteristics variables exclusively to the activity at the Superfund site. Earlier models, not reported here, presumed linear effects over time of distances from other locational amenities or disamenities. Here, however, we preserve the opportunity for non-monotonic effects over time, due to proximity to other geo-coded features.

[19] For example, Bui and Mayer (2003) approach sociodemographic change as follows: "Fixed amenities, including school test scores, the percentage of middle-aged households, and a location proxy, are assumed to be constant, so we use the value from the base year (t), or in some cases an earlier year when these values were taken from the U.S. Census." They do allow for changes in local economic factors, such as town-level manufacturing employment and the unemployment rate, and use these variables as controls, but assert that while these factors may be jointly endogenous with housing prices, the short time-span of their study permits them to assume that these are exogenous."

[20] For a theoretical example in the case of local public goods, rather than environmental threats, see Wellisch (1994) and Hoel (2004)