A Meta-Analysis of the Effect of Environmental Contamination and Positive Amenities on Residential Real Estate Values

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Abstract This paper addresses the effects of environmental contamination and positive amenities on proximate residential real estate property values in the United States. Contamination sources include leaking underground storage tanks, superfund sites, landfills, water and air pollution, power lines, pipeline ruptures, nuclear power plants, animal feedlots and several other urban nuisance uses. The study summarizes a literature review of 75 peer-reviewed journal articles and selected case studies, and generates a data set of about 290 observations that contain information about each study's loss (the dependent variable), with the independent variables being distance from the source, type of contamination, urban or rural environment, geographic region, market conditions and several other variables. Ordinary least squares is used to determine the effect of the contamination variables on reduction in property value. Broad contamination types, amenities, selected economic regions, distance from the source, information, research method and several other variables are statistically significant.

This research addresses how proximity to source influences environmental contamination effects on residential property values. Environmental sources that influence change property values include superfund sites, leaking underground storage tanks (LUSTs), landfills, air and water pollution, pipeline ruptures, nuclear power plants, overhead transmission lines, roads and several other urban nuisance uses. The paper begins with summarization of a literature review of 58 peer-reviewed technical journal articles and selected case studies from among over 100 articles and over 500 hours of research. Research findings are distilled into a data set of 230 observations that contain information about each study's dollar property value loss (the dependent variable), with the independent variables being distance from source, type of contamination, information, urban or rural environment, local and national market conditions, information about the contaminative event, remediation, study type and several other variables. Another 17 articles and 62 observations were gleaned from literature on views, parks, beaches and other positive amenities and their effect on residential sales price. Regression analysis is used to determine the effect of contamination and amenity variables on sales price, expressed in dollars or percent.

Contamination affects property values through impact on the real estate bundle of rights. These include the rights to possess, enjoy, control and dispose of real property. A loss can occur in ways other than the discounted sale (*i.e.*, inability to access capital, finance or refinance, delay of sale, etc.). See Simons, Bowen and Sementelli (1999) or Jackson (2001) for a review how a loss can occur. The sales prices studied in this research are just the net proceeds in the disposal part of the real estate bundle of rights (realized capital loss), and do not consider the timing of sale. Conversely, positive amenities can provide additional value to property.

Meta-analysis has traditionally been used for clinical studies and never widely applied to other research disciplines. The main findings are that survey and case study methodologies consistently have a higher property value loss than regression analysis. While this observation has often been assumed, this study solidifies and quantifies the difference between methodologies. Other results are limited to the specific models and discussed in depth in their respective section. The motivation for conducting such an involved study is to determine the feasibility of developing a predictive model for analyzing environmentally-contaminated real estate, as well as whether different types of contamination can be included in the same model. This paper strives to understand and analyze the relevant literature.

Literature Review

There has been one meta-analysis of similar scope for air pollution, and three comprehensive literature reviews on the effect of contamination on real estate values. These are covered below. In addition, Simons (2006) conducted a literature review of over 100 peer-reviewed articles on proximity influence (both positive and negative) for residential and commercial property, which is the source of the data set for this study. Despite several excellent international studies, the dataset consists of the literature pertaining to the United States due to difficulties in finding comparable economic indicators for non-U.S. studies.

Smith and Huang (1995) conducted a meta-analysis of 37 air pollution studies providing 86 estimates of marginal willingness to pay (MWTP) for reduction of PM10 (air pollution particulate of ten microns in diameter) during 1982–1984. The hedonic meta-analysis provides an average of the marginal values estimated under specific circumstances across several U.S. cities. The Ordinary Least Squares (OLS) regression model and the MAD econometric model were employed. Using the MAD estimator, a one unit reduction of PM10 ($\mu g/m^3$) resulted in an average MWTP (price increase) of $110 in 1992 dollars, or about 0.1% of property value for each unit reduction in air pollution. Their study was based on reconstructed data, and there were influential outliers that affected the results substantially. Their approach validates the use of OLS and related statistical techniques for this type of study.

Three other literature reviews on the broad subject of contamination and property values have recently been published in peer-reviewed journals. All three are thorough and logical. However, none of the studies made an attempt to statistically compare results, opting instead for a descriptive approach within contamination types or land use categories.

Farber (1998) focused on the theory and empirical outcomes for about 50 articles mostly on landfills, solid waste, superfund sites and other large projects, on residential property values. He used studies dated back to the 1960s. His analytical framework was from the public benefit-cost perspective, and covered the theory and methodology issues for both revealed preferences (*e.g.*, for actual sales using hedonic regression analysis) and stated preferences (using contingent valuation analysis). He found considerable agreement in the gradient effects across three post-announcement studies (with good public information), and that sanitary landfills and coal-fired utilities had comparable gradients. He also concluded that chemical refineries and nuclear power plants had roughly comparable gradients, and that the zonal effects of refineries and sanitary landfills were quite comparable and substantial (Farber, 1998: 11–12). Factors affecting property value included type of facility, distance, information (relative to an opening or closing date), thin markets and the employment effects of the source. He also brought his results to a base year for analysis.

Boyle and Kiel (2001) do not address theory, reviewing instead over 30 exclusively hedonic price studies and their effect on residential property. Their study is organized into air pollution, water quality, undesirable land uses, multiple pollution sources and which neighborhood variables are important. They focus on getting results into a same base year for comparison, and look to see if effects change over time, and with new information. They find that air studies produce mixed results, and posit that measurement factors are not generally known to homebuyers. The water quality studies consistently produce negative signs and statistical significance where theory would predict it, but with fluctuation in dollar amounts. Readily visible factors like water clarity and information announcements, and distance from water, are important factors. The studies on undesirable land uses also consistently produce negative signs and statistical significance where theory would predict it, but with considerable fluctuation in dollar amounts. Factors such as distance, information, neighborhood characteristics and visibility are important factors.

Jackson (2001) considered about 45 articles that dealt with the effects of environmental contamination on real estate, covering real estate appraisal theory and sales price analysis. The appraisal theory coverage includes stigma, mortgage financing, marketability of frozen assets, risk premium adjustment to the discount rate, market demand and timing of sale with respect to remediation. Other transaction-specific items, notably possibility of third-party lawsuits and indemnification of buyers by sellers, are also addressed. In terms of the quantitative review, Jackson reviewed about 20 articles that had empirical results for residential and commercial property affected by landfills, petroleum, superfund sites and similar uses. His articles included hedonic regression analysis, case studies and reported appraisal outcomes. The residential studies were published from 1982 on. He looks at effects over time, distance, in different markets, and at sales price discounts (some found no effects) and other reported effects on transaction rates and seller financing. Jackson offers no final observations on the consistency of the findings, other than that 15 studies showed negative effects and 4 showed no effects, and that intervening factors may play a role. He calls for a more systematic study and additional research for non-residential property.

To summarize, the three literature reviews and consideration of the theory concerning the effects of contamination on property values reveal that the effect of contamination or another amenity on property value is based on several factors, including: land use type, distance from the source, pathway, passage of time, existence of the condition, information, calendar year, urban or rural environment and market conditions. In some cases, indemnification, the presence of litigation, may also play a role. Finally, study type (*e.g.*, regression, case study, survey) should be controlled for because they may also generate different results.

Model and Data

The review of the literature on this topic has revealed a number of factors that can affect the price of residential real estate from environmental contamination, other neighborhood factors or offsite amenities. The dependent variable is the real change in property value in 2003 dollars. The regression model for this study is expressed as:

$$\begin{aligned} REALVAR = {} & \beta_0 + \beta_1 REALVAL + \beta_2 GEO + \beta_3 CONTCOND \\ & + \beta_4 LOGDIST + \beta_5 CONTTYPE + \beta_6 LITIG \\ & + \beta_7 INFO + \beta_8 URB + \beta_9 UNEMP \\ & + \beta_{10} CONV30RT + \beta_{11} LOGN + \beta_{12} STUDY + \varepsilon. \end{aligned} \tag{1}$$

Where these factors are variables or vectors as follows:

REALVAR = Property value diminution variation in 2003 dollars (dependent variable). An alternative specification is *DIMPERC* the real loss in percent, used with other negative amenities. A third variation is *ABSVALREALVAR*, is the absolute value, used when positive amenities are mixed together.

REALVAL = Unimpaired property value in 2003 dollars.
GEO = U.S. economic geographic location based on Salomon Brothers definitions: Farmbelt, Industrial Midwest, Mid-Atlantic Corridor, Mineral Extraction, New England, Northern California, South and Southern California.
CONTCOND = Influence condition is either in remediation or ongoing (ongoing), is the result of a sudden event (sudden), or is in post-remediation (NFA Postrem).
LOGDIST = Log of distance from the property to the source of contamination. For zones, the midpoint was used. If a property was adjacent to a site, the default distance was set at 0.00001 miles.
CONTTYPE = Type or source of contamination: including nuclear power plant or manufacturing facility (*NUKEMANUF*); a landfill, hazardous waste site, or Superfund site (*SUPERFILL*); linear sources such as roads, power lines, railroad tracks and pipelines (linear); groundwater contamination from leaking underground storage tanks and other sources (groundwater); air pollution including that form concentrated animal feeding operations (air*CAFO*); or urban disamenity including airport noise, sex offenders and rental property (urban disamenity). The positive amenity category (*POSITIVE*) includes views, proximity to parks, and new housing construction.
LITIG = The study was conducted for or the sale was part of litigation.
INFO = Information was disclosed based on the announcement of contamination (announcement of bad), the announcement of closing (announcement of closing), or common knowledge (common knowledge) at time of sale.
UNEMP = Unemployment rate in the county of sale in 1999.
CONV30RT = Conventional 30-year mortgage rate for the sale year.
URB = Intra-urban market location urban (urban), suburban (suburban), rural (rural) or mixed (mix) market where sale was recorded.
LOGN = Log of number of impacted properties from study (log of sample).
STUDY = Study methodology, such as hedonic regression (regression), survey (survey), or case study (case).
ε = Error term.

Data Set

The data set for this study is based on a detailed literature review conducted by Simons (2004). A list of the articles reviewed is included as Appendix A. This detailed review included about 75 peer-reviewed technical journal articles and selected case studies published since 1980, covering the empirical effects of contamination on residential and commercial property. It also covers a few dozen technical journal articles addressing the effects of positive amenities on property value. The 58 negative amenity articles used in this research represent the vast majority of residential empirical articles reviewed in the other three literature reviews on the topic.[1] No known literature review has been compiled on positive amenities, so the 17 articles abstracted and utilized in this research are without comparison. The list of these articles is shown in Appendix B.

This literature review is organized based on type of contamination or influence. Each study generated 1–12 usable observations. Each observation contains about 40 variables about the property, sale location and year, contamination, sale amount, unimpaired value of similar property in the area, location from the influence or source, with the other economic data also available. This literature review on negatively impacted residential properties generated a total of 228 observations. The positive amenity group had 17 articles yielding 62 observations (shown below in parentheses), in the following groups:

- *LINEAR* (power lines, pipelines, railroad tracks, roads, 45 observations);
- *SUPERFILL* (superfund sites, landfills, hazardous waste sites, 75 observations);
- NUKEMANUF (nuclear power plants, manufacturing facilities with beneficial employment and/or positive tax base effects beyond contamination, 34 observations);
- *URBAN DISAMENITY* (shopping centers, sex offenders, rental property, 15 observations);
- *AIR* (air pollution including concentrated animal feeding operations, 35 observations);
- *GROUNDWATER* (water pollution from LUSTs and other sources, 24 observations); and
- *POSITIVE* (positive amenities including beach access, views, park and riparian area proximity, new housing construction, 62 observations).

The positive amenity group (*POSITIVE*) presents unique modeling issues, and thus are run separately at the end of this analysis. This was accomplished primarily to determine if there is any symmetry in proximity influence, and to determine the order of magnitude of the parameter estimates. Unless otherwise noted, positive amenities are not discussed until the last section of the paper.

Since the data on negative amenities were based almost exclusively on peer-reviewed articles, all of the observations are either residential or land zoned for residential use. Hedonic regression dominated the methodology typology, consisting of 72% (164) of all observations. Surveys accounted for 31 observations and case studies provided an additional 26 observations. The "other" study category, consisting of sale-resale analysis, conjoint analysis and similar techniques not in the previous categories added another 7 observations.

The change in property value (*REALVAR*) is the dependent variable in this research, although a model was also run with percent diminution (*DIMPERC*, calculated as *REALVAR*/*REALVAL*). An important independent variable is unimpaired property value price (*REALVAL*). In cases where either one or the other was missing, the median home value for the sale locality from the most time-proximate decennial census was used and then inflated or deflated based on the overall Consumer Price Index for that year to get the estimated home value in 2003 dollars. If the change in property value was given in dollars rather than percent and no median sales price existed in the study, unimpaired property value was derived by dividing the dollar loss by the reported percentage reduction in value. In cases where a study covers multiple years, the average year was used. In studies using multiple periods, each period became a single observation in the data and the average year was used to determine property value.

The geographic variable (*GEO*) comes from the economic region definitions set forth by David Hartzell and others from Salomon Brothers for the purpose of real estate portfolio diversification analysis in the late 1980s, and highlighted in Malizia and Simons (1991). The Salomon Brothers' Economic Geography of the United States has eight distinct geographic regions.[2] A map of these regions is included in Appendix C.

Condition (*CONTCOND*) focuses on the environmental condition of the affected property at the time the study was conducted. In some cases, as in an explosion or chemical spill, it happened suddenly at a single point in time with a definite date corresponding to it. In other cases, such as noise from a railroad or airport, the effect is ongoing. The effect is also ongoing if the source of contamination is presently in remediation. For some studies, the property was in post-remediation and/or had received No Further Action status. A dummy variable was created for each of these situations.

The natural log (*LOGDIST*) of distance was used to convert miles from the distance from the source location. There was a wide range of variation in the distance variable, from 25 miles for a nuclear power plant to zero in cases of mold, asbestos, groundwater or similar on-site forms of contamination. For studies that used zones or buffers, the midpoint was used.[3]

There were six general types of contamination based on the overall sample.[4] These categories were needed because of the relatively small sample size. The groups were created because the expected effects of each type were of a similar magnitude and from the same general pathway. The large operating plant category (*NUKEMANUF*) includes manufacturing plants, airports and nuclear plants that have a large tax base. This category is of particular interest because it has positive location effects (access to jobs, large positive tax base impacts, and sometimes large amounts of open space), which may offset negative effects of potential explosions or other hard-to-predict events that have a high degree of uncertainty. The (*SUPERFILL*) variable contains landfills, hazardous waste sites and Superfund sites. These sites had a relatively small overall tax base, and limited jobs. Linear sources of negative proximity influence (*LINEAR*) are classified as power lines, railroads, roads and pipelines. Groundwater (*GROUNDWATER*) focused on the type of contamination, and included general water pollution studies, effects from

LUSTs, water bound PCBs and other sources. Air pollution (*AIR*) comprised sources such as particulate matter without a known source, mold, asbestos, or similar forms of airborne contamination, including concentrated animal feeding operations (*CAFOs*). Urban disamenities (*URBAN*) included a wide range of urban phenomena, including proximity to sex offenders, traffic density from shopping centers, proximity to concentrations of rental property and airport noise.

Many of the peer-reviewed technical journal articles were prepared by researchers with purely an academic interest in the determining the property effects from an environmental source. Several studies were also involved in litigation, such as a class action suit in response to contamination. In the case of concentrated animal feeding operations, the lawsuit may only include one adjacent property due to their relatively remote locations. Other litigation includes cases against governmental entities with tax assessment authority. Hence, a litigation dummy (*LITIG*) was included to determine if these sales were more likely to sustain larger losses.

The information variable (*INFO*) captures the amount of media or other public exposure received regarding the source of contamination. This dummy had three classifications: common knowledge, announcement of a bad thing and announcement of closing. Common knowledge refers to the obvious; most people can see a nuclear power plant or large industrial plant or understand the source of noise from an airport or a railroad in their backyard. Additionally, an explosion or similar sudden event is also considered common knowledge. Announcement of a bad thing is the discovery of the contamination, such as a study conducted that revealed groundwater contamination or the release of a radioactive cloud. Announcement of closing occurs when the source is closed, and often occurred with landfills that had reached capacity.

Two other variables were inserted to control for variation in economic market conditions. The unemployment variable (*UNEMP2K*) used the 1999 unemployment rate in the county of sale (from the 2000 Census) and served as a proxy variable for local economic conditions on the demand side of the housing market. To control for the national economy and interest rates for the year of sale, the annual average rate of the conventional 30-year mortgage (*CONV30RT*) was included.

The urban variable (*URB*) addresses intra-urban location of the sales area, as a proxy for market depth. This variable was specified as urban, suburban, rural, or mixed. Some studies mixed either urban and suburban or suburban and rural depending on the location of the contamination.

The study methodology (*STUDY*) and log of the number of impacted properties (*LOGN*) were also included to control for the type of research conducted. The study methodology dummy is one of four categories: regression, case, survey, or other. There were several studies that did not fit in any of the first three, such as pre- and post-analysis research.[5] The number of impacted properties ranged from several thousand for a hedonic regression to only one for a case study.

One final note merits mention before discussing the model results. Some of the results are dated and may not be indicative of changes in either the market or existing laws. The disclosure laws from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) changed in 1994 and again in 2003. The 1994 change required disclosure of environmental hazards to residents, which likely heightened awareness of nearby contamination to prospective homebuyers. The 2003 change, largely in response to possible terrorist threats, included several chemicals that were not sources of contamination, but nearby existing hazards (EPA Legislative website). Despite the changes in laws and market behavior, there is no indication that it affected the results of each included study, as well as the overall meta-analysis.

Regression Diagnostics

The data for negative amenities were checked for multicollinearity between independent variables and report the VIF and TOL indicators along with the model results. No variables had multicollinearity problems, since all scored well below the VIF cutoff of 10.0. The data set was also screened for outliers, and a model was run with some outliers excluded. To test for heteroscedasticity, a scatterplot was run of the residuals of the dependent variable. No fanning or cone-shaped pattern was evident; however, several outliers with large losses were present below the trend line. As a result, the outlier run was performed with these additional observations excluded.

Exhibit 1 contains descriptive statistics for the negative factors data set. The average loss was $15,055, or 9.5%, for a home with an unimpaired value of $157,818. The typical distance was slightly less than two miles from the source. Most other important factors are dummy variables, and this exhibit reflects their presence in the data set (*e.g.*, 77 sales from the industrial Midwest, 154 sales with common knowledge, 57 with litigation).

Results

A number of models were run. The overall model with negative amenities contains the entire set of 228 observations. This model was later run without outliers. To avoid a meta-analysis pitfall, called a filebox effect, a smaller dataset using no more than five observations per study was also used. Of the 228 observations, 34 were associated with zero property value loss. These observations were included in all of the models to minimize bias in the effects of contamination on property value.

The base model included all residential sales affected by negative proximity influences. Exhibit 2 contains results for this full model consisting of all 228 observations. The *F*-Statistic was 23.9, and the adjusted R^2 was .75. This means the variables in the model explain 75% of the variation in the decrease in property values.

Exhibit 1 | Descriptive Statistics

	Range	Min.	Max.	Mean	Std. Dev.
Diminished Property Value	$473,623	−$438,198	$35,425	−$15,055	$45,038
Property Value	$1,158,722	$25,278	$1,184,000	$157,878	$143,848
Year of Sale	29	1973	2002	1989	6.50
Log of Distance	14.73	−11.51	3.22	−4.36	5.76
Unemployment Rate 2000	9.23	2.01	11.24	6.13	2.17
Conventional 30-Year Mortgage Rate	10.09	6.54	16.63	9.97	2.17
Log of Sample Size	5.30	0	5.30	2.48	1.11
Geographic Regions					
Northeast	27				
Industrial Midwest	77				
Mid-Atlantic	25				
South	28				
Farmbelt	9				
Mineral Extraction	17				
Southern California	16				
Northern California	22				
U.S.	7				
Contamination Condition					
Ongoing	207				
Sudden	15				
NFA Post-remediation	6				

Exhibit 1 | (continued)

Descriptive Statistics

	Range	Min.	Max.	Mean	Std. Dev.
Source of Contamination					
Nuclear Power Plant, Manufacturing	34				
Landfill, Hazardous Waste, Superfund	75				
Linear	45				
Groundwater	24				
Air, CAFO	35				
Urban disamenity	15				
Litigation	57				
Information					
Common knowledge	154				
Announcement of a bad thing	53				
Announcement of a closing	9				
Location					
Urban	186				
Suburban	8				
Rural	14				
Mix	20				
Study Methodology					
Regression	164				
Case	26				
Survey	31				
Other	7				

Note: Valid $N = 228$.

Exhibit 2 | Full Model

	Beta	Std. Error	Std. Beta	*t*-Stat.	Sig.	Tolerance	VIF
(Constant)	24057.984	16272.584		1.478	0.141		
Real 2003$ value	−0.232	0.016	−0.741	−14.882	0.000	0.453	2.206
Northeast	10001.824	7450.501	0.072	1.342	0.181	0.391	2.556
Industrial Midwest	−11745.621	6577.420	−0.124	−1.786	0.076	0.234	4.267
South	−21074.724	7913.008	−0.154	−2.663	0.008	0.336	2.975
Farmland	−2986.366	11019.416	−0.013	−0.271	0.787	0.493	2.030
Mineral Extraction	12321.428	8983.833	0.072	1.372	0.172	0.407	2.456
Southern Calif.	24.081	10117.610	0.000	0.002	0.998	0.339	2.946
Northern Calif.	20172.658	8209.452	0.133	2.457	0.015	0.386	2.591
U.S.	22769.792	12773.813	0.087	1.783	0.076	0.467	2.141
Sudden	9666.305	7362.430	0.070	1.313	0.191	0.401	2.495
NFA Postrem	60833.211	25636.382	0.089	2.373	0.019	0.790	1.266
Log of distance	873.157	426.798	0.112	2.046	0.042	0.377	2.656
Nukemanuf	−25885.182	7013.232	−0.205	−3.691	0.000	0.363	2.752
Superfill	1531.336	6384.856	0.016	0.240	0.811	0.254	3.941
Groundwater	−16610.194	9710.841	−0.115	−1.710	0.089	0.246	4.060
AirCAFO	−19303.986	7069.330	−0.155	−2.731	0.007	0.349	2.864
Urban disamenity	−12018.997	10410.890	−0.066	−1.154	0.250	0.340	2.938
Litigation dummy	−9002.766	5201.625	−0.087	−1.731	0.085	0.447	2.237
Announcement of bad thing	−1452.143	6809.926	−0.015	−0.213	0.831	0.238	4.206
Announcement of closing	52377.579	14067.737	0.227	3.723	0.000	0.302	3.309
Suburban	−8508.088	10232.289	−0.035	−0.831	0.407	0.640	1.563
Rural	11095.010	9027.876	0.059	1.229	0.221	0.483	2.071
Mix	−1198.789	6887.093	−0.008	−0.174	0.862	0.597	1.674
2000 unemployment rate	1878.386	1070.011	0.091	1.755	0.081	0.421	2.378
30yrrt	342.978	978.125	0.017	0.351	0.726	0.500	2.000
Log of sample size	1212.765	2635.505	0.030	0.460	0.646	0.258	3.874
Case	−45612.525	10514.199	−0.328	−4.338	0.000	0.196	5.089
Survey	−10561.260	6151.500	−0.081	−1.717	0.088	0.510	1.960
Other	2054.510	10991.003	0.008	0.187	0.852	0.631	1.585

Notes: Dependent Variable: real 2003$ dim. Reference categories: Mid-Atlantic, ongoing, linear, common knowledge, urban, regression. $N = 228$, DF = 198, adj. $R^2 = .75$, $R^2 = .78$, *F*-Statistic = 23.9.

The reference categories for the model were as follows: Mid-Atlantic region, common knowledge of contamination, ongoing site condition, linear contamination sources (the one with the smallest and most localized losses) and regression analysis methodology. A positive parameter estimate means losses from contamination are smaller, a negative number means losses increase. The following variables had statistically significant results:

- *REALVAL*: Property losses due to proximity to environmental contamination were $0.23 higher for every additional dollar in real unimpaired value, and were statistically significant at a 99% level of confidence, holding all else constant.
- *GEO*: In terms of economic geography variables, compared with the Mid-Atlantic region (reference category), the Northern California region and the U.S. overall had lower losses of approximately $21,000, significant at 90% or better. This may be related to more rapid overall property appreciation. The South region had larger losses of approximately $21,000, significant at 95%, and the Industrial Midwest region had losses that were $11,700 deeper at a 90% level of confidence. Other regions were not significantly different than the Mid-Atlantic region.[6]
- *CONTCOND*: The condition of the contamination variables is compared to the reference category where the environmental condition was ongoing. Contaminated properties that were either in post-remediation or received an NFA had a large reduction in losses (over $60,000) and were significant at the 95% level of confidence. The plausibility of this parameter estimate's magnitude is limited. It may be unduly influenced by a few observations. Sales proximate to with sudden events (*e.g.*, explosions) had losses that were smaller by approximately $6,000, but results were only significant at the 80% level of confidence, beyond normal scientific standards.
- *LOGDIST*: The logarithm of distance is positive (873) and significant at the 95% level. As a property is located away from the source, the effect on price is positive and losses get smaller.

CONTTYPE: Type of contamination: compared with a property sold proximate to linear sources of nuisance, such as railroad tracks and roads, and power lines and pipelines, which is the reference category.

- *NUKEMANUF*: Nuclear power plants and manufacturing facilities with substantial ongoing employment had the expected negative sign, and were significant at the 95% level. The parameter estimate of −$25,900 was quite large.
- *SUPERFILL*: Superfund sites and incinerators, landfills and hazardous waste sites were not significantly different from linear effects. Several of these observations had little or no effect.
- *GROUNDWATER*: Groundwater contamination including water quality as well as contamination without a known source had a significant, negative

effect, resulting in losses that were $16,600 larger (significant at the 90% confidence level).

- *AIR*: Air pollution including CAFOs also had a significant, negative effect, with losses that were $19,300 larger (significant at the 99% confidence level).
- *URB DIS*: Urban disamenity (sex offenders, shopping malls, airport noise) had the expected negative sign, but it was not statistically significant.
- *LITIG*: Litigation has a significant negative effect on value. Properties involved in litigation had losses that were $9,000 larger, at a 90% level of confidence, holding all else constant.
- *INFO*: The announcement of a bad thing was negative but not significantly different from an ongoing source or a source in remediation. The announcement of a closing was significant and positive ($52,300, with a 99% level of confidence) supporting the theory that property values increase with news of the source's closing. However, the magnitude of the positive effects is almost too large to be plausible.
- *UNEMP*: The local unemployment rate variable was significant and positive. This result was unexpected, given that the theory that increased unemployment has a positive affect on property values is counterintuitive.
- *STUDY*: Case study (−$45,600) and survey methods (−$10,600) were both statistically significant at the 90% level or better. Unlike the reference category of hedonic regression models that use a large data sample, case methods often have larger losses because they focus on one or a few properties more likely to show a definite change. Survey methods are also negative because respondents are likely to have better and more complete information than actual sales, where information may not be complete. It is interesting to note that log of sample size was not statistically significant.

Outlier Analysis

Exhibit 3 contains the results of the residential model without outliers. The dependent variable was percentage reduction in property value.[7] There were several observations that were located a very large distance from the source of contamination (greater than ten miles); results showed a positive effect in response to contamination (indicating some misspecification in the statistical models), or observations that had an unusually high prevailing mortgage rate (over 15%). Observations with unimpaired property values in excess of $500,000 were removed.[8] Running the same model as Exhibit 2 without these outliers resulted in a data set of 184 observations. The outliers included two studies that dealt with vacant residential land and multifamily structures.

The *F*-Statistic dropped substantially from the original model to 4.9, with a parallel decrease in the adjusted R^2 .38. Despite the loss in overall goodness of

Exhibit 3 | Outlier-free Model

	Beta	Std. Error	Std. Beta	*t*-Stat.	Sig.	Tolerance	VIF
(Constant)	−0.043	0.103		−0.415	0.679		
Real 2003$ value	0.000	0.000	−0.137	−1.493	0.137	0.402	2.487
Northeast	−0.041	0.042	−0.101	−0.956	0.340	0.305	3.275
Industrial Midwest	−0.087	0.038	−0.323	−2.266	0.025	0.166	6.027
South	−0.074	0.045	−0.168	−1.658	0.099	0.330	3.034
Farmland	−0.101	0.053	−0.171	−1.897	0.060	0.417	2.395
Mineral Extraction	0.021	0.044	0.046	0.475	0.636	0.366	2.736
Southern Calif.	0.023	0.059	0.048	0.394	0.694	0.225	4.438
Northern Calif.	0.041	0.042	0.094	0.968	0.335	0.358	2.791
U.S.	0.007	0.068	0.008	0.107	0.915	0.571	1.750
Sudden	0.064	0.040	0.156	1.605	0.111	0.356	2.811
NFA Postrem	0.115	0.084	0.113	1.374	0.172	0.495	2.019
Log of distance	0.006	0.003	0.256	2.212	0.028	0.252	3.961
Nukemanuf	−0.097	0.040	−0.240	−2.412	0.017	0.340	2.938
Superfill	−0.048	0.041	−0.180	−1.195	0.234	0.148	6.738
Groundwater	−0.085	0.052	−0.219	−1.627	0.106	0.187	5.348
AirCAFO	−0.091	0.038	−0.266	−2.428	0.016	0.281	3.561
Urban disamenity	−0.043	0.059	−0.089	−0.724	0.470	0.224	4.460
Litigation dummy	−0.061	0.030	−0.207	−2.049	0.042	0.331	3.025
Announcement of bad thing	0.012	0.041	0.043	0.290	0.772	0.154	6.484
Announcement of closing	0.128	0.074	0.203	1.715	0.088	0.241	4.148
Suburban	0.001	0.052	0.001	0.013	0.990	0.640	1.563
Rural	−0.102	0.053	−0.196	−1.921	0.057	0.325	3.075
Mix	−0.013	0.034	−0.030	−0.367	0.714	0.493	2.030
2000 unemployment rate	0.004	0.006	0.070	0.669	0.504	0.307	3.261
30yrrt	0.014	0.005	0.227	2.491	0.014	0.408	2.450
Log of sample size	−0.003	0.016	−0.026	−0.195	0.846	0.194	5.151
Case	−0.116	0.057	−0.294	−2.028	0.044	0.160	6.242
Survey	−0.063	0.031	−0.170	−2.033	0.044	0.482	2.077
Other	0.083	0.053	0.124	1.576	0.117	0.549	1.820

Notes: Dependent Variable: DIMPERC (Property diminution in percent). Reference categories: Mid-Atlantic, ongoing, linear, common knowledge, urban, regression. $N = 184$, DF = 154, adj. $R^2 = .38$, $R^2 = .48$, F-Statistic = 4.9.

fit, this outlier-free model makes good economic sense. Many of the variables significant in the first model became slightly more significant in the model without the outliers. In some cases, parameter estimates also changed substantially, and these are reflected in percent because the dependent variable is percent (not real) diminution in property value. The Northern California region (4.1%) and U.S. (0.7%) maintained their expected positive signs, but were no longer significant at the 90% level of confidence. Farmland remained negative (−10.1%) and was significant near the 95% level. Post-remediation NFA had a reduction of 11.5% on losses but was not significant. Two variables not significant in the previous model but significant here are the rural location variable and the 30-year conventional mortgage rate. The rural variable had a larger loss of 10.2% at the 90% level. The 30-year conventional mortgage rate (1.4% at the 95% level) is now significant. This suggests that the expected rate of real estate appreciation does not cause any reduction in potential buyers from higher interest rates. Overall, the model presented in Exhibit 3 had the most plausible parameter estimates of any of the models (*e.g.*, none appeared excessively high or low). Exhibit 3 also displays the highest VIF values and weaker *t*-tests, which brings into question the reliability of several coefficients.

Common Validity Threats to Meta-Analysis

Unlike conventional regression analysis where the unit of observation is individual sales, meta-analysis poses certain additional validity threats due to the nature of data collection. Wolf (1986: 9) has identified a number of potential validity threats to meta-analysis, many of which were avoided in the current study by the selection of only peer-reviewed studies. These include: having an identical dependent variable (dollar/percentage loss in value) for all studies, reporting instead of interpreting the results from each article, having rigorous oversight on data input procedures and by having a strong theoretical basis for finding results.

However, there are a few threats. One of the more important is the "file drawer effect" (studies with no significant findings get buried in a file drawer, hence a bias toward studies with significant findings); sensitivity of the results where multiple observations are derived from one study (Wolf 1986: 24–45), and using weighting schemes where studies had a different sample size.[9]

The file drawer effect looks at the potential bias of peer-reviewed journals to accept research that only has findings supporting a theory. While there are several studies accounting for 34 observations in the overall model that show no effect, most indeed have some significant negative results, as predicted by theory. The test for this problem is to determine the "fail safe *N*," the number of studies with a positive finding that would be required to "overturn" the findings of statistical significance. Following Wolf (1986: 38–39), the formula to determine the fail safe (N_{fs}) where $p = .05$ (*e.g.*, a 95% level of significance) is: $N_{fs.05} = (\Sigma Z/1.645)^2 - N$, where ΣZ = the sum of individual Z scores (the standardized score associated with each p value) and N = the number of studies. Solving for $N_{fs.05}$, the number of studies (not observations) needed to invalidate the statement that contamination negatively affects property values. The sum of the Z scores was 8.11. There were 58 studies, and assuming the absolute value of the equation, it would take 34 studies with a positive finding to overturn the results.

In order to test for study bias issues and using the maximum number of observations, the model was run with a maximum of five observations from any one peer-reviewed study. Studies with more than five observations were input into SPSS and five observations were then randomly selected. The remaining observations were taken out of the model. This diminished the degrees of freedom available ($N = 160$). The F-Statistic for the five observations maximum model was 21.2 and the adjusted R^2 was .785. Unlike the previous models, the constant is significant and positive. In general, similar signs and results are expected, but statistical significance will drop. Therefore, the threshold of statistical significance is relaxed to a confidence level of 85%.

For this model, the key variables of unimpaired value and distance, the results in Exhibit 4 were essentially the same as in the basic model displayed in Exhibit 2. However, the five observation maximum model had several different variables that were statistically significant when compared to the base model. The Northeast region was positive, showing a reduction of $11,268 from the Mid-Atlantic reference category, and was significant at the 15% level. The South, Northern California and U.S. regions are now found to be statistically insignificant. The *SUDDEN* variable is also positive at $10,828 and at the 15% level, indicating that property values affected by a sudden contamination event sell for a higher amount. Among the intra-urban variables, the suburban variable shows larger losses of $15,173 at the 10% level, which is higher than urban properties. This may be a result of greater market depth, but may also reflect higher initial sales prices. In Model 4, unlike the base model, groundwater, litigation and the unemployment rate have all become insignificant. The case and survey method variables continue to be negative, but their significance increases in both cases compared to earlier models.

Adding in Positive Amenities

As a final analysis, 62 observations from 17 peer-reviewed articles that address the effect of positive amenities on property values were added. The types of positive amenities included beach frontage, water view (including desert riparian areas, river, lake and ocean), parks, golf courses and new housing construction. The studies included residential land uses, but a few included residential lots prior to development, rather than existing houses. The research hypothesis is that markets can internalize proximity to positive factors and that this effect can be determined, holding all other factors in the model constant.

However, there are some conceptual issues, the primary one of which is that proximity to these features is positive, rather than negative. Thus, the distance

Exhibit 4 | Five Observations Max Model

	Beta	Std. Error	Std. Beta	*t*-Stat.	Sig.	Tolerance	VIF
(Constant)	37559.92	16215.22		2.316	0.022		
Real 2003$ value	−0.18	0.01	−0.709	−12.230	0.000	0.399	2.505
Northeast	11268.32	7577.76	0.081	1.487	0.139	0.454	2.203
Industrial Midwest	−12390.90	6410.21	−0.140	−1.933	0.055	0.256	3.905
South	−11084.33	8164.75	−0.097	−1.358	0.177	0.260	3.840
Farmland	4004.47	10501.94	0.021	0.381	0.704	0.423	2.365
Mineral Extraction	9007.70	8717.44	0.065	1.033	0.303	0.343	2.916
Southern Calif.	1031.53	10234.09	0.006	0.101	0.920	0.361	2.771
Northern Calif.	9368.38	8093.56	0.065	1.158	0.249	0.423	2.362
U.S.	−13367.36	11954.14	−0.067	−1.118	0.266	0.371	2.699
Sudden	10828.01	7251.98	0.090	1.493	0.138	0.369	2.709
NFA Postrem	46378.98	22401.25	0.090	2.070	0.040	0.711	1.407
Log of distance	617.23	420.82	0.090	1.467	0.145	0.360	2.778
Nukemanuf	−17485.90	7052.61	−0.154	−2.479	0.014	0.349	2.865
Superfill	−1316.68	6317.99	−0.015	−0.208	0.835	0.243	4.112
Groundwater	−13506.52	9939.17	−0.100	−1.359	0.177	0.249	4.015
AirCAFO	−13617.72	7018.98	−0.126	−1.940	0.055	0.320	3.123
Urban disamenity	−9851.90	10217.23	−0.059	−0.964	0.337	0.362	2.762
Litigation dummy	−4061.32	4820.70	−0.045	−0.842	0.401	0.471	2.125
Announcement of bad thing	−1728.19	6580.44	−0.020	−0.263	0.793	0.240	4.164
Announcement of closing	50878.33	21168.88	0.218	2.403	0.018	0.163	6.124
Suburban	−15173.23	9061.23	−0.081	−1.675	0.096	0.568	1.761
Rural	59.89	11185.56	0.000	0.005	0.996	0.255	3.920
Mix	1223.33	6522.79	0.009	0.188	0.852	0.578	1.729
2000 unemployment rate	827.62	1077.82	0.043	0.768	0.444	0.432	2.314
30yrrt	−97.11	1018.98	−0.005	−0.095	0.924	0.462	2.163
Log of sample size	−3385.06	2833.48	−0.094	−1.195	0.234	0.219	4.570
Case	−51944.43	13584.26	−0.414	−3.824	0.000	0.115	8.723
Survey	−16105.96	6263.07	−0.134	−2.572	0.011	0.495	2.021
Other	1276.32	9990.70	0.006	0.128	0.899	0.530	1.885

Notes: Dependent Variable: real 2003$ dim. Reference categories: Mid-Atlantic, ongoing. Reference categories: Mid-Atlantic, ongoing linear, common knowledge, urban, regression. N = 160, DF = 130, adjusted R^2 = .79, R^2= .82, F-Statistic = 21.2.

variable can be expected to become insignificant because the effects of new observations on sales price run in the opposite direction than negative amenities. Also, the geographic distribution of the positive amenities is not as broad as for the negative amenities: most of the observations were in the Northern California and South coastal regions, with a few in the Midwest. The dependent variable was also changed, using the absolute value of the magnitude of the change in dollars instead. A dummy variable for the positive amenities was also added.

Exhibit 5 shows the results of a model run with the 228 negative amenities observations, plus the 62 positive amenity observations. The model had an R^2 of .63 and an F-Statistic of 14.8.[10] This is adequate, but lower than with the previous comparable model containing fewer observations of only negative factors. The parameter estimate of the *POSITIVE* variable was positive and statistically significant at the 99% level of confidence. However, several other variables that were significant under earlier runs with just negative models became insignificant. A large negative or positive parameter estimate means that the value effects due to proximity to an environmental attribute are greater, and a small parameter estimate closer to zero means the impact is less. The following variables had statistically significant results:

- *REALVAL*: Property values due to proximity to positive or negative environmental attributes were $0.27 higher for every additional dollar in real unimpaired value. This value was statistically significant at the 99% level of confidence, holding all else constant;
- *GEO*: Compared with the Mid-Atlantic region (reference category), the Northeast (−$13,963), Southern California (−$30,328) and the U.S. region (−27,642) were significant at the 85% level or better. Unlike in the first model, Northern California, South and the Industrial Midwest regions were no longer significant, which is expected due to the offsetting combination of positive and negative studies on these regions. The other regions were not significantly different from the Mid-Atlantic region in either model.
- *CONTCOND*: The condition of the contamination variables is compared to where the environmental condition was ongoing (reference category). Properties receiving an NFA or that were in post-remediation continued to be significant at the 95% level of confidence. The few observations in this category may exert greater influence than can be realistically expected. Sudden events were not significantly different from the ongoing sources.
- *LOGDIST*: The logarithm of distance is negative (−111) but not significant. Unlike the first model focusing on proximity to negative effects, this result was expected. Introducing interaction terms to isolate distance for positive or negative attributes did not change the lack of significance.

CONTTYPE: Compared with a property sold proximate to linear sources of nuisance, which is the reference category.

Exhibit 5 | Full Model including Positive Amenities

	Beta	Std. Error	Std. Beta	*t*-Stat.	Sig.	Tolerance	VIF
(Constant)	−352.738	20732.549		−0.017	0.986		
Real 2003$	0.266	0.018	0.769	14.542	0.000	0.508	1.967
Northeast	−13962.826	9476.326	−0.089	−1.473	0.142	0.393	2.546
Industrial Midwest	9096.404	8592.284	0.088	1.059	0.291	0.205	4.870
South	4970.477	9014.822	0.041	0.551	0.582	0.261	3.831
Farmland	18783.687	13446.290	0.071	1.397	0.164	0.548	1.826
Mineral Extraction	−7517.679	10711.699	−0.042	−0.702	0.483	0.404	2.474
Southern Calif.	−30327.869	11184.110	−0.172	−2.712	0.007	0.354	2.822
Northern Calif.	−11846.742	9172.574	−0.099	−1.292	0.198	0.244	4.093
U.S.	−27641.705	15723.240	−0.093	−1.758	0.080	0.511	1.956
Sudden	7190.605	9121.629	0.046	0.788	0.431	0.424	2.359
NFA Postrem	−42774.499	18079.852	−0.133	−2.366	0.019	0.449	2.225
Log of Distance	−110.791	443.787	−0.014	−0.250	0.803	0.468	2.135
Nukemanuf	14984.633	8863.555	0.105	1.691	0.092	0.366	2.730
Superfill	−7336.750	8344.406	−0.070	−0.879	0.380	0.225	4.440
Groundwater	1303.279	12156.383	0.008	0.107	0.915	0.265	3.767
AirCAFO	538.992	8702.970	0.004	0.062	0.951	0.371	2.699
Positive	27672.917	7788.091	0.248	3.553	0.000	0.292	3.422
Urban Disamenity	−2757.847	12910.358	−0.013	−0.214	0.831	0.364	2.746
Litigation Dummy	19086.802	6983.865	0.166	2.733	0.007	0.387	2.585
Announcement of bad thing	868.311	8165.361	0.008	0.106	0.915	0.254	3.933
Announcement of closing	−13996.399	15896.511	−0.053	−0.880	0.379	0.392	2.552
Suburban	−1645.491	11905.268	−0.007	−0.138	0.890	0.631	1.585
Rural	−12149.809	7918.104	−0.082	−1.534	0.126	0.498	2.010
Mix	−4236.639	8968.512	−0.023	−0.472	0.637	0.577	1.734
2000 unemployment rate	1268.266	1019.763	0.065	1.244	0.215	0.523	1.911
30yrrt	−2253.065	1180.558	−0.104	−1.908	0.057	0.484	2.067
Log of sample size	−5497.991	3006.477	−0.131	−1.829	0.069	0.276	3.623
Case	13815.971	12154.904	0.086	1.137	0.257	0.247	4.049
Survey	1931.742	7496.193	0.013	0.258	0.797	0.555	1.801
Other	−12024.160	13854.640	−0.040	−0.868	0.386	0.658	1.519

Notes: Dependent Variable: absolute value of real 2003$ dim. Reference categories: Mid-Atlantic, ongoing, linear, common knowledge, urban, regression. $N = 290$, DF = 259, $R^2 = .63$, adj. $R^2 = .59$, F-Statistic = 14.8.

- *NUKEMANUF*: Nuclear power plants and manufacturing facilities with substantial ongoing employment was positive at $14,985 and significant at the 90% level. This parameter estimate was somewhat less than the −$25,900 estimate in the negative model.
- *SUPERFILL*: Landfills, incinerators, hazardous waste sites and Superfund sites were not significantly different from linear effects. Most of these observations had minor impacts or no effect.
- *GROUNDWATER*: Groundwater contamination including water quality and contamination without a known source had a positive effect, but was not significant. The loss of significance from the previous model was likely due to the dilution in the model from incorporating positive amenities.
- *AIR*: Air pollution including CAFOs, like the groundwater variable, was positive and also not significant.
- *POSITIVE*: Proximity to positive environmental attributes was positive ($27,673) and significant at the 99% level of confidence. Properties located near a positive attribute were worth a 25% premium.
- *URB DIS*: Urban disamenity had the expected negative sign, but was not significant.
- *LITIG*: Litigation continues to have a significant effect on value. Lawsuits should have a negative effect on property value. Since none of the positive observations contained litigation, the parameter estimate of $19,087 was likely due to negative effects. This parameter estimate was significant the 99% level of confidence.
- *INFO*: Announcement of a bad thing was slightly positive but not significant from common knowledge (reference category). Announcement of a closing was negative but also not significant.
- *UNEMP*: The local unemployment rate was positive but not significant. This result was unclear from the previous model. It could reflect the previous observations that increased unemployment should not have a positive effect on property values or it could be due to the incorporation of the absolute value of property value.
- *CONV30RT*: The conventional 30-year mortgage rate was negative (−$2,253) and significant at the 90% level of confidence. A higher mortgage rate should lead to higher property values, not lower, making this result against theory. Real estate is positively correlated with inflation, as is the mortgage rate. Therefore, higher mortgage rates are associated with higher interest rates.
- *URB*: Compared to urban areas (reference category), both suburban and mix were negative but not significantly different from urban. Rural was also negative and significant at the 85% level of confidence. Rural properties near a positive or negative effect sold for $12,150 less than an unaffected property.

- *LOGN*: The log of the sample size was negative and significant at the 90% level of confidence. All of the positive observations used regression analysis to determine the effects on property value, accounting for the change in significance from previous studies.
- *STUDY*: Case, survey and other methods were not significantly different from studies using regression analysis. Case and survey were both positive, while other methods was negative. This result was expected due to the additional 62 observations for positive amenities utilizing regression analysis, which diminishes the significance of the other methods.

Conclusion

This paper has addressed the overall effects of proximity influence of environmental contamination on residential real estate property values. Empirical research from peer-reviewed studies were distilled into a data set that contains information about each study's loss (the dependent variable), with the independent variables being geographic location, distance from the source, condition of the contaminated site, urban, suburban, rural, or mixed environment, market conditions and a few other variables. Regression analysis was used to determine the effect of contamination variables on the real change in value.

To make an apples-to-apples comparison across the negative models, the diminution in value variable was used as the dependent variable in each of the three models (Exhibit 6). Upon running the models, the standardized beta weights and significance for all variables in each model was analyzed. In all three negative environmental proximity models (overall, outlier-free and 5-observation maximum), the following variables were significant and had the expected signs: the unimpaired value (+), the Industrial Midwest region (−), a site in post-remediation or which had received its NFA (+), *NUKEMANUF* (pollution sources with a large tax base and substantial employment, with a negative sign), air pollution (−), announcement of a closing (+), case method (−) and survey method (−). The first two models (overall and outlier) had the following additional significant variables: South and Northern California regions (+), the log of distance (+), groundwater contamination (−), litigation (−) and the unemployment rate (+ and contrary to theory). Any two models indicated the following variables were significant: post-remediation/NFA (+), distance (+) and groundwater pollution (−). The findings indicate that regression studies systematically show a lower level of losses compared with other methodologies.

The model that included both negative and positive observations had several variables that were also significant in the full negative model. The unimpaired value (+), U.S. region (−), post-remediation/NFA (−), *NUKEMANUF* (+) and litigation (+) were all significant. Other variables that were significant only in the combined model were the Northeast and Southern California regions (−), positive amenity (+), rural (−), *30YRRT* (−) and *LOGN* (−). Due to the positive effects

Exhibit 6 | Comparison of the Three Negative Amenity Models

	Exhibit 2 Full Model		Exhibit 3 Outlier-free Model		Exhibit 4 Five Observations Max		Number of Models Showing Variable as Significant at the 15% Level
	Beta	Sig.	Beta	Sig.	Beta	Sig.	
(Constant)		0.141		0.141		0.022	
Real 2003$	−0.741	0.000	−0.402	0.000	−0.709	0.000	3
Northeast	0.072	0.181	−0.099	0.391	0.081	0.139	1
Industrial Midwest	−0.124	0.076	−0.429	0.005	−0.140	0.055	3
South	−0.154	0.008	−0.094	0.374	−0.097	0.177	1
Farmland	−0.013	0.787	0.077	0.415	0.021	0.704	0
Mineral Extraction	0.072	0.172	0.078	0.450	0.065	0.303	0
Southern Calif.	0.000	0.998	0.029	0.824	0.006	0.920	0
Northern Calif.	0.133	0.015	−0.014	0.897	0.065	0.249	1
U.S.	0.087	0.076	−0.013	0.871	−0.067	0.266	1
Sudden	0.070	0.191	0.159	0.128	0.090	0.138	2
NFA Postrem	0.089	0.019	−0.055	0.532	0.090	0.040	2
Log of Distance	0.112	0.042	0.305	0.015	0.090	0.145	3
Nukemanuf	−0.205	0.000	−0.236	0.033	−0.154	0.014	3
Superfill	0.016	0.811	−0.226	0.163	−0.015	0.835	0
Groundwater	−0.115	0.089	−0.428	0.003	−0.100	0.177	2
AirCAFO	−0.155	0.007	−0.090	0.442	−0.126	0.055	2
Urban disamenity	−0.066	0.250	−0.227	0.088	−0.059	0.337	1
Litigation dummy	−0.087	0.085	−0.101	0.356	−0.045	0.401	1

Exhibit 6 | (continued)

Comparison of the Three Negative Amenity Models

	Exhibit 2 Full Model		Exhibit 3 Outlier-free Model		Exhibit 4 Five Observations Max		Number of Models Showing Variable as Significant at the 15% Level
	Beta	Sig.	Beta	Sig.	Beta	Sig.	
Announcement of bad thing	−0.015	0.831	0.303	0.058	−0.020	0.793	1
Announcement of closing	0.227	0.000	0.475	0.000	0.218	0.018	3
Suburban	−0.035	0.407	−0.139	0.079	−0.081	0.096	2
Rural	0.059	0.221	−0.183	0.080	0.000	0.996	1
Mix	−0.008	0.862	−0.198	0.027	0.009	0.852	1
2000 unemployment rate	0.091	0.081	−0.078	0.489	0.043	0.444	1
30yrrt	0.017	0.726	0.090	0.356	−0.005	0.924	0
Log of sample size	0.030	0.646	−0.124	0.356	−0.094	0.234	0
Case	−0.328	0.000	−0.457	0.003	−0.414	0.000	3
Survey	−0.081	0.088	−0.107	0.232	−0.134	0.011	2
Other	0.008	0.852	−0.060	0.482	0.006	0.899	0

associated with this model, several variables were counteracted. A majority of the positive studies occurred in Northern California and South regions, offsetting the negative studies and making the effects insignificant. Since all of the studies regarding positive amenities used regression analysis, the remaining methodology variables lost significance due to the premium accorded to properties proximate to positive environmental features.

The most consistent result from all three models is that the use of survey and case study techniques provides larger estimates of property losses regarding contamination than regression studies do (Exhibit 7). Case studies may be considered to be somewhat subjective based on the case researcher, and may often be chosen due to their dramatic, atypical conditions. Surveys also may have potential bias due to the subjectivity of the respondents, who may lack the expertise to make an accurate estimation of the impact of the contamination, or hypothetically bias issues.

Basic descriptive analysis on each of the respective methodologies demonstrates widely different outcomes. For the 164 observations that utilize regression analysis, the largest loss was $42,480 and the mean loss was $6,443. These values correspond to a percentage loss in value of 29% for the largest loss and a mean loss of 4%. Case studies, while often highlighting worst-case scenarios and often only one home, had losses ranging from zero to $438,200 (88%) of home value, with a mean of 21%. Survey methods also had larger losses in terms of percent. The maximum loss was $96,669 (94%), with a mean loss of $17,164 (19%).

Analyzing correlation coefficients further illustrates differences between methodologies. For regression, the correlation coefficients for urban disamenities, common knowledge of the disamenity, occurrence in an urban area, mortgage rate and log of the sample size were all positive and significant at the 5% level. Variables that were negatively correlated and significant at the 5% level included air pollution, litigation, announcement of a bad thing, announcement of a closing, rural area, mixed (urban, suburban and/or rural) locations, case method, survey method and other methods. The positive correlation to urban location is expected based on the fact that urban governments are more likely to keep better records more conducive to utilizing regression analysis whereas rural areas may not provide an adequate sample size to run regression. Despite the significance of several correlation coefficients, the only correlations stronger than .5 were related to data collection: the log of the sample size (.572), case method (−.574), survey method (−.635) and other methods (−.285). The correlation of case study methods to survey methods was significant at the 5% level and negative (−.142). These correlations suggest that case and survey methods yield similar results despite their slightly negative correlation. Case and survey methods, compared to regression analysis, are highly and significantly negatively correlated, resulting in higher property loss values. Further, regression studies may show lower loss figures because information about the source of contamination may not be known to all buyers and sellers. In other words, specific disclosure of the contaminative conditions may not have taken place.

Exhibit 7 | Correlation Coefficients for Regression, Case and Survey Methodologies

Regression		Case		Survey	
Log of sample size	0.57	Announcement of closing	0.42	Mixed location	0.42
Diminution in percent	0.44	Rural location	0.31	2000 Unemployment rate	0.25
Diminution in value	0.31	Sudden contamination	0.30		
Common knowledge	0.28	Air pollution	0.27		
Urban location	0.21	Value	0.25		
Urban disamenity	0.17	Groundwater contamination	0.19		
Mortgage rate	0.14	Litigation	0.18		
		Announcement of a bad thing	0.14		
Survey methodology	−0.64	Log of sample size	−0.62	Regression methodology	−0.64
Case methodology	−0.57	Regression methodology	−0.57	Diminution in percent	−0.30
Other method	−0.29	Diminution in value	−0.42	Urban location	−0.24
Air pollution	−0.25	Common knowledge	−0.31	Log of sample size	−0.22
Announcement of closing	−0.22	Diminution in percent	−0.31	Sudden contamination	−0.15
Mixed location	−0.22	Survey methodology	−0.14	Case methodology	−0.14
Litigation	−0.20	Ongoing	−0.14	Groundwater contamination	−0.14
Announcement of a bad thing	−0.18				
Rural location	−0.17				

Note: For variables significant at the 5% level.

Regression analysis provides a more conservative, statistically accurate estimation of property value losses, but may not always be possible in some cases of contamination, such as mold where the level of contamination is often confined to the immediate home. Where multiple methods exist, an average may be more appropriate rather than taking the method providing the highest or lowest value. The negative value on the Midwest variable is also not surprising given the long history of industrialization and contamination in this region. Sites in post-remediation, receiving NFA status, or announcing their closure are likely to have a positive impact once the contamination threat is greatly reduced or completely removed. Air pollution studies might also be worth revisiting in cases where the source of air pollution has implemented greater contamination control and/or reduction measures.

The primary focus of this paper has been on the effects of contamination on property values, especially off site. All these effects are negative, or at best neutral. Observations from positive amenity factors, such as views, proximity to beaches, parks, etc. were inserted. Then it was determined that there is little symmetry between positive and bad things. It also confounded the simplicity of the terminology, from bad things, to amenities of positive or bad nature, from decrease in property values to change in property values, and from pre-or-post remediation to existence of condition effecting value. Absolute value of the dependent value was used instead of loss, and dummy variables were included for the amenities. Additional research may focus on creating more variables to better differentiate the effects between negative and positive influences.

Further studies may include testing the strength of the variables showing significance across all three models in the meta-analysis. Given the loss of manufacturing companies in the U.S., especially the Midwest, have the values of homes previously impacted by these companies rebounded in value or appreciated at an equal or greater rate than surrounding areas? Controlling for the impact of these factors may yield conclusive, but not generalizable, results. Can a study be conducted using case study, survey and regression analysis methodologies to show how the methodology may affect results when applied to the same situation? The existing literature fails to analyze such a situation, but this merits future research. Additional research might compare studies conducted in years surrounding major changes in environmental laws to determine if the laws had any impact on the market. A study of this nature would analyze sales before and after some type of law, such as disclosure. Finally, laws may be important, but the role of terrorism could also be analyzed by comparing sales before and after 9/11/2001 based on proximity to nuclear power plants and other major producers of electricity.

Future research could also incorporate commercial property, with additional dummy variables for land use type and revised outlier cutoffs. Additional research may also lead to the construction of predictive models based on the regression coefficients, to determine, within an error band, the expected range of property value losses for certain situations within the experience of the model's data set. Based on this predictive model, policies for adjusting housing values based on a specific source or type of contamination may be possible. If feasible, this predictive model could provide a realistic benchmark for the accuracy of future studies based on the contamination source or type, location, distance and methodology employed in the study.

Appendix A

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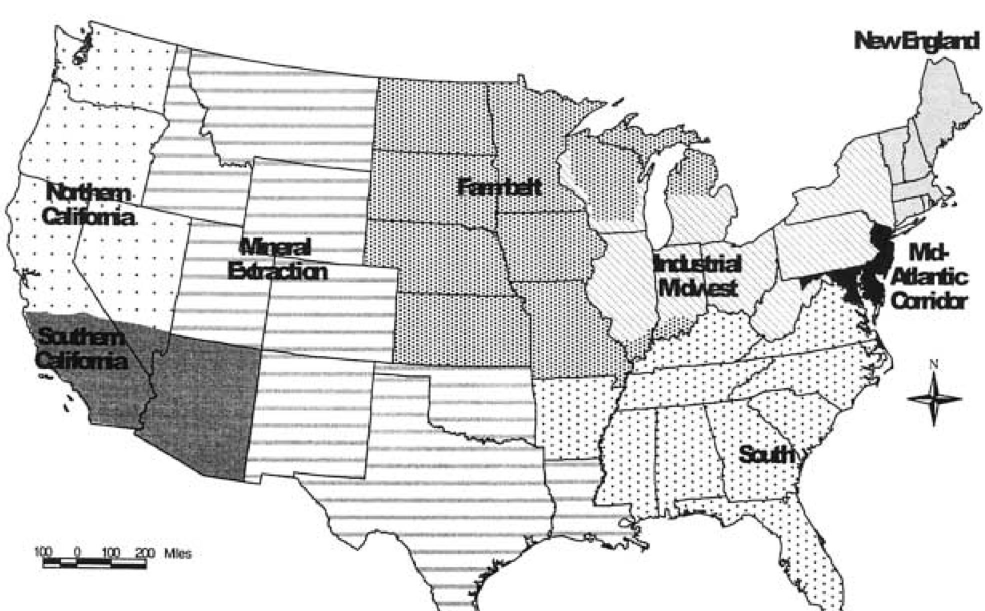
Appendix C

Salomon Brothers Asset Management's Economic Geography of the United States



Hawaii is in the Southern California region and Alaska is in the Mineral Extraction region.

Endnotes

[1] Depending on the context and the way proximity to the source of contamination is measured, some of these articles demonstrated positive price effects. This phenomenon occurred most often in the case of high voltage overhead transmission lines. These studies showing positive price effects were included in the full model for what theory would deem to be negative amenities, but not in the outlier model.

[2] New England consists of all states east of New York. The Industrial Midwest stretches from New York to Pennsylvania, West Virginia, Ohio, southern Michigan, central and northern Indiana and Illinois and southeastern Wisconsin, including Milwaukee. The Farmbelt includes northern Michigan and Wisconsin, extreme southern Indiana and Illinois, Missouri, Iowa, Minnesota, North and South Dakota, Nebraska and Kansas. The Mid-Atlantic Corridor covers Delaware, Maryland and New Jersey. The South runs from Virginia and Kentucky south to the gulf states of Florida, Mississippi and Alabama. It also includes Arkansas but not Louisiana. Based on Louisiana's oil industry, it is part of the Mineral Extraction region, which also includes Texas, Oklahoma and New Mexico, then moving northwest across Colorado, and west to east central Nevada, with Idaho and Montana as its northern border. Alaska is also included in the Mineral Extraction region. Southern California includes southern California, southern Nevada and Arizona. Northern California includes northern California north of Los Angeles, northwestern Nevada, Oregon, Washington and Hawaii.

[3] Since logging 0 is not possible, .00001 replaced zero to enable the model to run without rejecting this variable.

[4] The original model had 14 different types of contamination. Of these 14, only PCBs were statistically significant at the 95% and 90% levels of confidence. At the 85% level of confidence, agricultural contamination, mainly from concentrated animal feeding operations, was statistically significant. Additionally, the model had positive signs for proximity to a Superfund site or landfill, indicating statistical issues, and contradicting theory that would indicate these sources would negatively affect property value.

[5] In the final model, only one or the other is used to minimize the likelihood of multicollinearity between the two.

[6] Based on the helpful comments of two anonymous referees, the model was re-run with a variable called *REALAPP* based on appreciation rates from 1990 to 2000. The variable was not significant (.688) and did not improve the adjusted R^2 (.739). A separate model was run with a variable called *REALMORT* based on the real mortgage rate calculated by subtracting the rate of inflation for a respective year by the mortgage rate. The variable was significant (.081) at the 10% level for the full model, but did not improve the overall adjusted R^2 (.74). The *REALMORT* variable was not significant in any of the other models.

[7] A model was also run with these observations where the dependent variable was real diminution in property value. The R^2 was .32.

[8] Many of these were influential outliers with respect to large losses and large residuals.

[9] This is not believed to be a problem because the log of study size variable is not statistically significant. Additionally, study type was controlled for and the results reported. The related problem of over-sampling from any study was also controlled for.

Although it may be possible to rerun the data set with artificial weights that reflect the source of the study, this was deemed to be unnecessary.

10 Other models run did not yield better results and only one resulted in an R value explaining more than 50% of the variation in the variables. These models included using absolute value of change in percentage of property values (R = .28), change in property values (R = .56) and percentage change in property values (R = .39) as dependent variables. Attempts to improve model accuracy by changing reference variables also did not produce improved model accuracy. Running models with only positive observations (N = 62) also did not produce better results. Using change in value as the dependent variable for a model on POSITIVE observations, the R^2 was .55 and with change in percentage of value, the R^2 was .23.

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