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The impact of hazardous waste on property values: The effect of lead pollution

This paper examines the impact of lead pollution on property values in Anniston, Alabama, one of the most polluted cities in the US. A hedonic house price analysis enabled us to examine the extent of lead contamination's effect on property values there, as well as property value losses due to the presence of an army depot. We estimated that lead cleanup would provide an increased property value of $1,140 per household and found that living 1 km closer to the polluting sites reduces property values by approximately 2%, a figure consistent with previous research regarding the connection between environmental disamenities and property values.

Keywords: hedonic analysis, environmental disamenities, externalities, urban economics

1 Introduction

The social costs of lead contamination are well documented, including both measurable health costs and difficult-to-measure effects on the IQs and wages of those affected. The Pew Center on the States (2010) found that over the lifetime of each US birth cohort, lead exposure increased national healthcare expenses by $11 to $53 million, resulted in lifetime lost earnings of $190 to $268 billion, increased special education expenses by $297 to $413 million and increased the costs resulting from behavioural and criminal problems by upwards of $1.7 billion. Thus, for the lifetime of those born at a particular time in the US, the total increase in social costs exceeds $192 billion, suggesting that decreasing human lead exposure would result in a non-trivial social benefit.

Studies of the social costs resulting from lead exposure neglect an important aspect that affects both the private and local public government sectors: decreases in residential property values. When property values decrease, local tax revenues are negatively impacted, causing reductions in public goods and services in affected areas. Our hypothesis is that lead pollution has a negative impact on property values, and we set out measure the size and statistical significance of the impact. To test our hypothesis, we analysed cases of lead contamination in bodies of water and soil, and then used a hedonic price model to determine the effect on property values. For the hedonic model (Rosen, 1974), the valuation of a good is strongly dependent on its attributes and characteristics. The price of the good can therefore be considered the sum of expenditures on its individual characteristics, where the prices of characteristics are implicitly determined in the model. The property value in our model was thus a function of its characteristics: $P(c_i)$ with $i = 1, 2, \ldots, n$ for each of the n characteristics. Point c_i is an equilibrium point on a hyperplane of n-dimensional space, and each point represents the value of the i^{th} characteristic of the good at that particular point. The hedonic model determines a competitive equilibrium on this hyperplane. $P(c_i)$ is therefore determined by the market conditions that are driving buyers and sellers to make choices. Choices made by agents within the market are optimal for both buyers and sellers and represent a trade-off among the set of all possible choices. The extent to which a disamenity affects property values can be determined by regressing property values based upon property characteristics.

This article is organized as follows: the next section presents existing studies in this area, section 3 presents the study case, section 4 describes the data, section 5 presents the econometric model, results from the regression models are discussed in section 6, and the final section concludes the article.

2 Literature review

There are several examples in the literature of the use of hedonic analysis to determine the value of non-market goods and to assess environmental and social costs through changes in property values. Diane Hite et al. (2000) used a hedonic house price model to quantify the economic impact of environmental disamenities on property values. That article focused on the effect of open and closed landfills on residential real estate prices. They found that closing landfills does not completely eliminate the social costs. It was also found that disamenities led to reductions in property values, contributing to significant loss of property tax revenues. Chau-Sa Ho and Hite (2008) investigated the effects of environmental health risks such as toxic waste dumping, the number of Superfund sites and cancer mortality on property values in the southeast US. They used a simultaneous spatial 2SLS model including hedonic price as a function of housing, neighbourhood, county and environmental characteristics. They found that property value is negatively affected by toxic waste dumping and cancer mortality. Jeff Anstine (2003) examined the impact of two noxious facilities on property values: a rubber-compounding factory that emits foul odours and visible air pollution and a heavy-metals manufacturing facility that uses low-level depleted uranium in its production process. He found that only noticeable disamenities impact the property value. Brid Gleeson Hanna (2005) tested the hypotheses that communities where polluting factories are present have lower property values and lower incomes compared to communities in cleaner areas. The findings suggest that living a mile closer to a polluting factory reduces property values by only about 1.9%, which is a smaller figure compared to other existing studies (although similar to our results).

Hedonic models have also been used outside the US. Anish Neupane and Kent Gustavson (2006) examined the impact of a contaminated site in Sydney, Nova Scotia and found a large negative effect on property values situated within a few hundred metres of the site. Overall, property value losses from the contaminated site in Sydney were estimated to be CAD 36 million. Arief Anshory Yusuf and Budy P. Resosudarmo (2007) determined the value of clean air in Jakarta using the hedonic model, regressing monthly rental prices based upon the structural characteristics of housing and the environmental characteristics (including the presence of six pollutants). Their results demonstrated that households would pay $38.72 per month to eliminate lead pollution (it is notable that lead was the only pollutant in the model that had a 5% significance level).

3 The study area

Lead is a chemical element with the symbol Pb and an atomic weight of 207.2 g/mol. It is considered a heavy metal, although this is a meaningless and misleading definition according to the International Union of Pure and Applied Chemistry (Duffus, 2002). Lead has ecotoxic properties, meaning that humans do not have an enzymatic system for homeostatic control of the substance. The US Environmental Protection Agency (2009) and the Centers for Disease Control and Prevention (2009) reported that lead poisoning (or saturnism) can cause a variety of negative health effects including behavioural and learning disorders. Individuals can be exposed to lead through air, water and food contamination. The fact that lead is colourless, odourless and flavourless increases the risk of exposure among individuals that use water from wells close to contaminated bodies of water. Although lead is poorly soluble in water, adjacent soils where lead concentrations are high can contaminate bodies of water via dissolution of Pb^{++} ions into the water (the water need only be slightly acidic). The soil itself can be contaminated by lead as a result of flaking lead paints, battery and other manufacturing processes, incinerators and the disposition of lead particles on the soil surface from vehicles using leaded fuel. Lead was used widely for many years until studies discovered the extent of potential hazards, especially for children under 6 years old with developing brains. Michael D. Lewin et al. (1999), using a multivariate linear regression model, predicted children's blood lead levels based on soil lead levels at four Superfund sites. Their model[1] demonstrated a significant positive association between soil lead levels and lead found in children.

Anniston represents a natural laboratory in which to implement a model and test the effects of lead pollution on property values. Anniston was the location of the Solutia Plant (Monsanto Corp.), which produced polychlorinated biphenyls (PCBs) between 1920 and 1970 (the date that PCB production

Figure 1: Spatial distribution of Anniston housing units (source: Calhoun County Alabama, 2005).

was banned). A previous study of Anniston (de Parisot, 2007) confirmed a decrease in property values due to environmental health risk perceptions among the inhabitants. This shows a strong correlation between decreasing values and an increase of PCBs in the soil. Anniston is also the home to the Anniston Chemical Army Depot, which, after the 1988 decision by the army to incinerate on-site chemical weapons, was converted to a weapons incinerator in August 2003, when destruction of M55 nerve agent rockets began. The disposal operations for blistering and nerve agents are expected to last until 2012.

Environmental health in eastern Alabama has long been the target of public health studies. D. Alan Hansen and George M. Hidy (1982) examined rain chemistry in the southeastern US from Alabama eastwards to Florida. Their results found elevated acid precipitations (pH < 5.0) during the period from the 1950s to 1970s. According to the authors, this was likely due to a substantial increase in population and industrial growth experienced by the region during that 20-year period.

The Environmental Protection Agency (EPA), in conjunction with 11 corporations (the respondents) operating in the Anniston area, entered into an agreement to investigate potential PCB and lead pollution caused by the respondents' corporations. The following is taken from the response to public comments regarding this agreement:

> EPA believes that the majority of the lead contamination in Anniston area that is not either naturally occurring or from typical urban activities such as lead paint or leaded gasoline, is associated with the operations of various industrial operations throughout the Anniston valley, including the plants owned and operated by Respondents. Unlike PCBs in Anniston, which are man-made and are primarily associated with the historic operation of the Monsanto plant, lead has been released into the Anniston area through a wide variety of ways. First, some lead is naturally occurring in the environment. Second, lead was used in a number of ways in urban areas – lead paint and leaded gasoline being the most ubiquitous sources. However, EPA has concluded that Anniston does have levels of lead contamination that exceed those which would be found in most similar small urban areas. (EPA, 2006: 16–17)

In 2002, the EPA began lead and PCB cleanup activities and so far has spent over $12 million for lead contamination cleanup in the Anniston area alone. The soil at over 2,000 residential properties was sampled for lead contamination. Approximately 342 samples exceeded the EPA safety threshold of 400 parts per million (ppm). At the time when the data for the study were collected, the EPA had cleaned up 133 of these 342 properties. According to the EPA, the lead contamination was caused by the industrial activities of 23 facilities, including the Monsanto Solutia plant. Those activities consisted of foundry activities, munitions manufacturing, automobile shredding, electroplating, and steel manufacturing and galvanizing (EPA, 2006).

Through interviews with hundreds of local residents and reviewing the records of foundry disposal practices, the EPA was able to document the common practice of using foundry sand as residential fill material. Lead contamination caused by surface runoff appeared to occur less commonly. The EPA also observed that lead had been released for many years through smoke stacks before the foundries started to use pollution-control devices. Using air models of lead dispersion, the EPA could also confirm that lead pollution had occurred in Anniston because of air contamination.

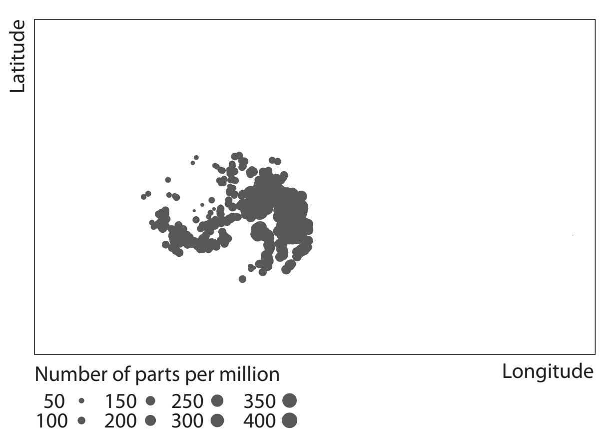


Figure 2: Lead concentration in Anniston (source: EPA, 2005).

Between 1928 and 1964, Monsanto used the lead pot process to produce PCB. This process created emissions of lead vapours into the air from the conversion units and maintenance on the conversion units. The EPA verified from Monsanto's records that lead was emitted into the air from the lead pot process and into Anniston waterways directly through Monsanto's own wastewater streams. Although there is no quantitative assessment of the volume of lead released from that process, an unidentified expert reported that Monsanto released approximately 258 tons of lead into the environment as part of the lead pot processing conducted during that period. Air modelling demonstrated to the EPA that the high concentration of lead in the air was expected to be located within a radius of 500 m from the stack.

4 Data description

The data used in this paper come from multiple sources containing detailed information regarding approximately 65,000 family housing units. The complete dataset includes information for 2005 from the Calhoun County Mapping Department and Tax Revenue Commission Service, EPA Toxic Release Inventory, GIS Spatial Data (EPA.gov/tri), Alabama Department of Education, Federal Bureau of Investigations Uniform Crime Statistics and Census STF3A Microdata at the census block group (CBG) level. The data included in our analysis is restricted to 4,783 pieces of information related to the Anniston area. The large dataset allows for the results' consistency and mitigates the substantial bias of the Instrumental Variable (IV) estimator that is typical of small case samples.

The key variables used in our analysis include the lot size in square feet for each property, house size in square feet, number of rooms, number of stories, existence of a pool or fireplace, age of the dwelling, percentage of white households per CBG, percentage of households below the poverty line per CBG, distance from the Anniston Army Depot, distance from bodies of water (expressed in km) and the logarithm of lead concentration in the soil. These variables were then related to nominal sales price data from the monthly CPI housing index for small cities in the southern US with January 2007 as the base period (01/2007 = 100). Due to the limited variation in local amenities (e.g., one school district, one park and no public transportation), these variables were not included in the hedonic model.

5 Econometric model and diagnostic testing

The price of a property (composite good) is a function of the structural, neighbourhood and environmental characteristics and a vector of spherical disturbances. Our hedonic model is specified based on that function in order to analyse the effects of lead contamination on property values in Anniston. In its econometric form, the model gives a property value equation (Equation 1).

$$\ln(\text{REALPRICE})_i = \beta_0 + \beta_1\ (\text{LAND\_AREA}) + \beta_2\ (\text{TOTAL\_SQUARE\_FT})_i + \beta_3\ (\text{ROOMS})_i + \beta_4\ (\text{STORIES})_i + \beta_5\ (\text{POOL})_i + \beta_6\ (\text{FIREPLACE})_i + \beta_7\ (\text{AGE})_i + \beta_8\ (\text{WHITE\_HH})_i + \beta_9\ (\text{POVERTY\_HH})_i + \beta_{10}\ (\text{DIST2INCIN})_i + \beta_{11}\ (\text{DIST2WATER})_i + \beta_{12}\ (\text{LEADMG})_i + u_i$$

$i = 1, 2, 3, \ldots, 4783$

Equation 1: Hedonic model of Anniston's housing market.

The dependent variable is REALPRICE, which represents the dollar value of each housing sales transaction (data from the CPI at the individual level). Figure 3 demonstrates that the vector of housing prices and the vector of land area both have a skewed distribution. To correct this problem, the variables were transformed by the natural logarithm to obtain a normal distribution (Wooldridge, 2006).

Table 1: Descriptive statistics of the variables

Variable	Mean	St. Deviation	Minimum	Maximum
REALPRICE	74,200	57,061	7.94	961,000
LAND_AREA	9,210	12,090	0	178,000
TOTAL_SQUARE_FT	1,520	501.8	504	9,500
ROOMS	6.35	1.51	1	16
STORIES	1.22	0.43	1	10
POOL (Dummy variable)	8.22%			
FIREPLACE (Dummy variable)	60.80%			
AGE	36	21.06	2	145
WHITE_HH	84	20.72	0	100
POVERTY_HH	9.52	5.88	5.36	27.60
DIST2INCIN	15,900	4,366	4,970	29,900
DIST2WATER	183	130	0	702
LEADMG	54.90	86.46	0	398

Housing characteristics are generally expected to positively affect property values. These characteristics included the size of the lot associated with each property (LAND_AREA), the total floor space of the house (TOTAL_SQUARE_FT), the number of rooms (ROOMS), the number of stories (STORIES), the presence of a swimming pool (POOL) and/or a fireplace (FIREPLACE), and the age of the house (AGE). The neighbourhood characteristics included the percentage of white households (WHITE_HH) and the percentage of households that live below the poverty line

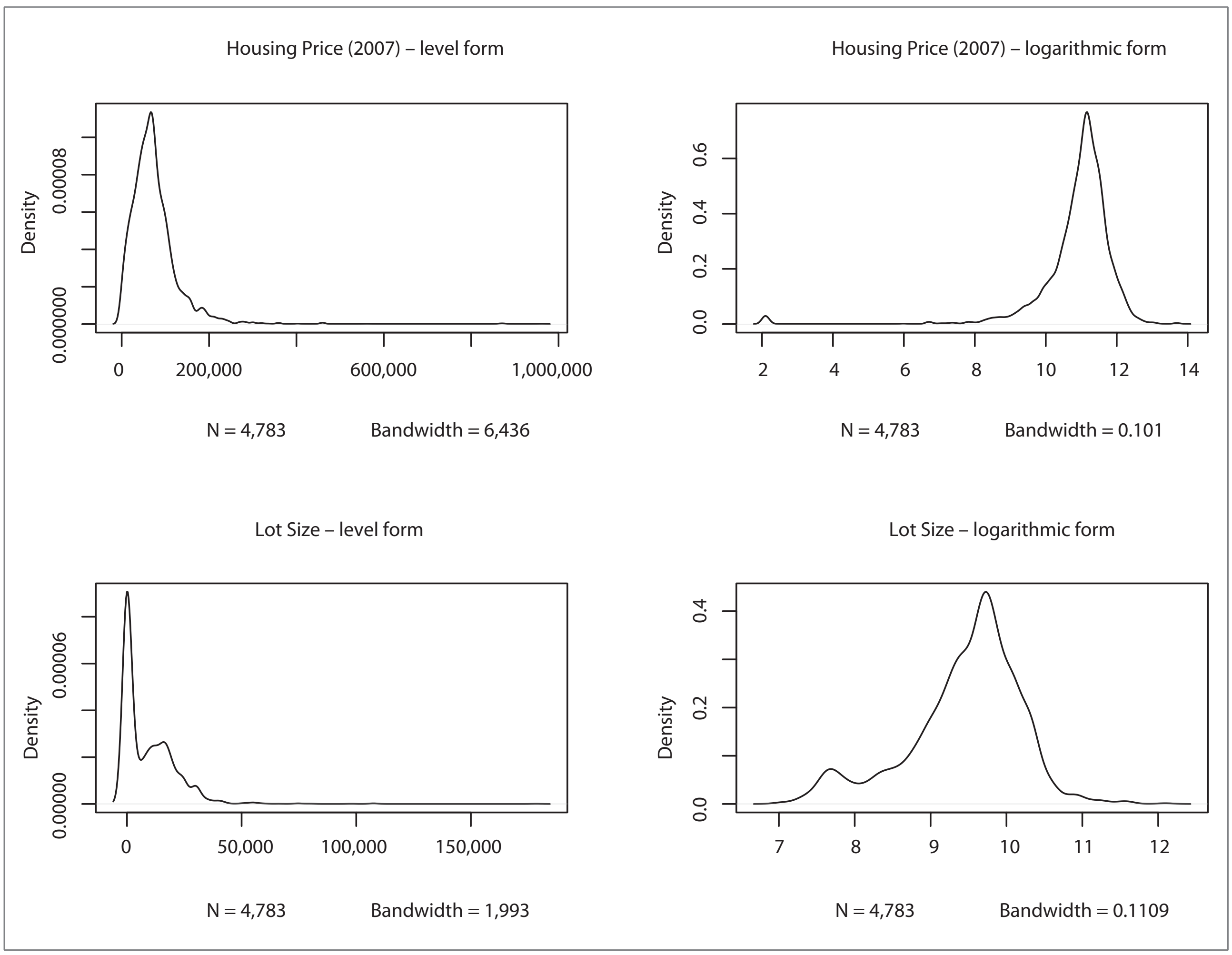


Figure 3: Distribution of housing price and lot size in Anniston.

(POVERTY_HH). Environmental characteristics were of particular interest in this study. They included the distance in kilometres from the Anniston Chemical Army Depot (DIST2INCIN), which was included as a control variable because we assumed that proximity to the incinerator would lower property value (e.g., households fearing a possible accident). Those environmental characteristics also included the variables that represented the risk of lead exposure, which were the most important for the study. The lead concentration (measured by the EPA during their testing in 2002 and expressed in mg per kg of soil[2]) for each of the properties (LEADMG) investigated in this model affects property value because households would want to avoid lead exposure. The distance in metres from the closest body of water (DIST2WATER) was the other important variable related to lead exposure. The effect of this variable is uncertain, however. A stream, for example, can have an aesthetic worth that adds more value to properties or it might represent a possible source of contamination, as in the Anniston example.

5.1 Model specification test

The variables used in hedonic models typically co-vary in a significant way. We therefore tested the models for multicollinearity. Table 2 shows the variance inflation factors. It is notable that all values were less than five, and thus the level of multicollinearity among variables is acceptable.

The RESET test (Ramsey, 1969) is commonly used to test for functional form misspecification. The assumption under the alternative hypotheses is that the model should include the powers greater than the model of the fitted response, the regressors and the first principal component. The absence of these terms, if the model is mis-specified, would result in an omission of variables and yield biased results. A standard F-test determines whether the additional terms are jointly significant in the model. At a 5% significance level, we rejected the null hypothesis that the original model was correctly specified.[3]

Table 2: Variance inflation factors

Variables	VIF(βi)
LAND_AREA	1.252
TOTAL_SQUARE_FT	1.573
ROOMS	1.677
STORIES	1.406
POOL	1.086
FIREPLACE	1.326
AGE	1.924
WHITE_HH	2.116
POVERTY	2.613
DIST2INCIN	1.333
DIST2WATER	1.027
LEADMG	1.351

Several combinations of terms of second and third powers and a log form of regressors were tested for joint statistical significance. The final, correct form is shown by Equation 2.

$$\ln(REALPRICE)_i = \beta_0 + \beta_1 \ln(LAND\_AREA) + \beta_2 (TOTAL\_SQUARE\_FT)_i + \beta_3 (TOTAL\_SQUARE\_FT)^2_i + \beta_4 (ROOMS)_i + \beta_5 (STORIES)_i + \beta_6 (POOL)_i + \beta_7 (FIREPLACE)_i + \beta_8 (AGE)_i + \beta_9 (WHITE\_HH)_i + \beta_{10} (POVERTY\_HH)_i + \beta_{11} (DIST2INCIN)_i + \beta_{12} (DIST2WATER)_i + \beta_{13} \ln(LEADMG)_i + u_i$$

$i = 1, 2, 3, ..., 4783$

Equation 2: Hedonic model including quadratic terms.

The squared ROOMS variable turned out to be insignificant for this specific model in contrast to our expectations based on other hedonic property value models (Wooldridge, 2006). House size appeared to have a quadratic relationship with the logarithm of price because the squared TOTAL_SQUARE_FT variable was significant at the 1% level. Figure 4 shows the quadratic relationship between property value and housing size in Anniston when the choice of consumers is not affected by other attributes.[4] The dashed line shows the non-linear relationship between the property value and the size of houses in Anniston when the choice of consumers is affected by other attributes.[5]

The Breusch-Pagan test for heteroscedasticity was performed for the model presented in Equation 2 and the null hypothesis of homoscedasticity was rejected.[6] The same determination is graphically depicted in Figure 5.

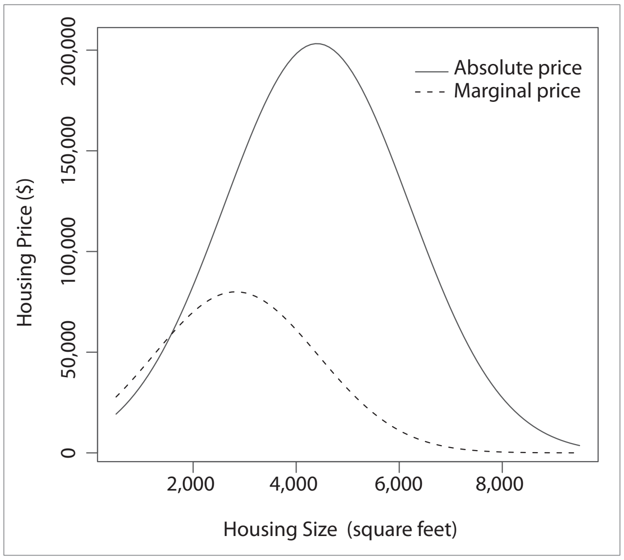
A weighted least squares test was therefore used as an unbiased estimator with heteroscedasticity correction. The procedure used to correct for heteroscedasticity was the one proposed by Wooldridge (2006). Once the regression for Equation 2 was performed, the residuals ($\hat{u}$) were saved and squared and the natural logarithm taken. This variable is referred to as $G = ln(\hat{u}^2)$ in the regression model in Equation 3.

$$G_i = \beta_0 + \beta_1 \ln(LAND\_AREA) + \beta_2 (TOTAL\_SQUARE\_FT)_i + \beta_3 (TOTAL\_SQUARE\_FT)^2_i + \beta_4 (ROOMS)_i + \beta_5 (STORIES)_i + \beta_6 (POOL)_i + \beta_7 (FIREPLACE)_i + \beta_8 (AGE)_i + \beta_9 (WHITE\_HH)_i + \beta_{10} (POVERTY\_HH)_i + \beta_{11} (DIST2INCIN)_i + \beta_{12} (DIST2WATER)_i + \beta_{13} \ln(LEADMG)_i + u_i$$

$i = 1, 2, 3, ..., 4783$

Equation 3: Auxiliary regression for Weighted Least Square.

The fitted values of Equation 3 were exponentiated to create $H = exp(\hat{G})$, and the weight used to obtain robust estimators was $W = 1/H$. The model in Equation 2 was also tested for endogeneity and the variable DIST2WATER was found to be significantly correlated with the error term u, re-



Note: 1,000 square feet = ~ 93 m^2

Figure 4: Housing price–housing size relationship in Anniston.

quiring implementation of a two-stage least squares (2SLS) regression analysis. The two candidate variables for DIST-2WATER were the exogenous variables LON and LAT (the longitude and latitude of each property). LON1 and LAT1 exhibit the following characteristics: Cov(LON,u) = 0, Cov(LAT,u) = 0, Cov(LON,DIST2WATER) ≠ 0 and Cov(LAT,DIST2WATER) ≠ 0. These characteristics suggest that these are appropriate variables. In other words, when the buyer purchases a house for an unknown reason in a specific location in Anniston, the purchasing decision is uncorrelated with the sales price agreed upon with the seller. In contrast, the reason for deciding to live in downtown Anniston or in the eastern part of the city may be affected by the aesthetic value of the proximity to a body of water and its impact on sales price.

The 2SLS was implemented using the regression of the endogenous variables on the exogenous variables of the reduced form equation (Equation 4).

$$DIST2WATER_i^* = \pi_0 + \pi_1 (LAND\_AREA) + \pi_2 (TOTAL\_SQUARE\_FT)_i + \pi_3 (TOTAL\_SQUARE\_FT)^2{}_i + \pi_4 (ROOMS)_i + \pi_5 (STORIES)_i + \pi_6 (POOL)_i + \pi_7 (FIREPLACE)_i + \pi_8 (AGE)_i + \pi_9 (WHITE\_HH)_i + \pi_{10} (POVERTY\_HH)_i + \pi_{11} (DIST2INCIN)_i + \pi_{12} \ln(LEADMG)_i + \pi_{13} (LON) + \pi_{14} (LAT) + \varepsilon_i$$

$i = 1, 2, 3, ..., 4783$

Equation 4: Reduced form of the first stage least square.

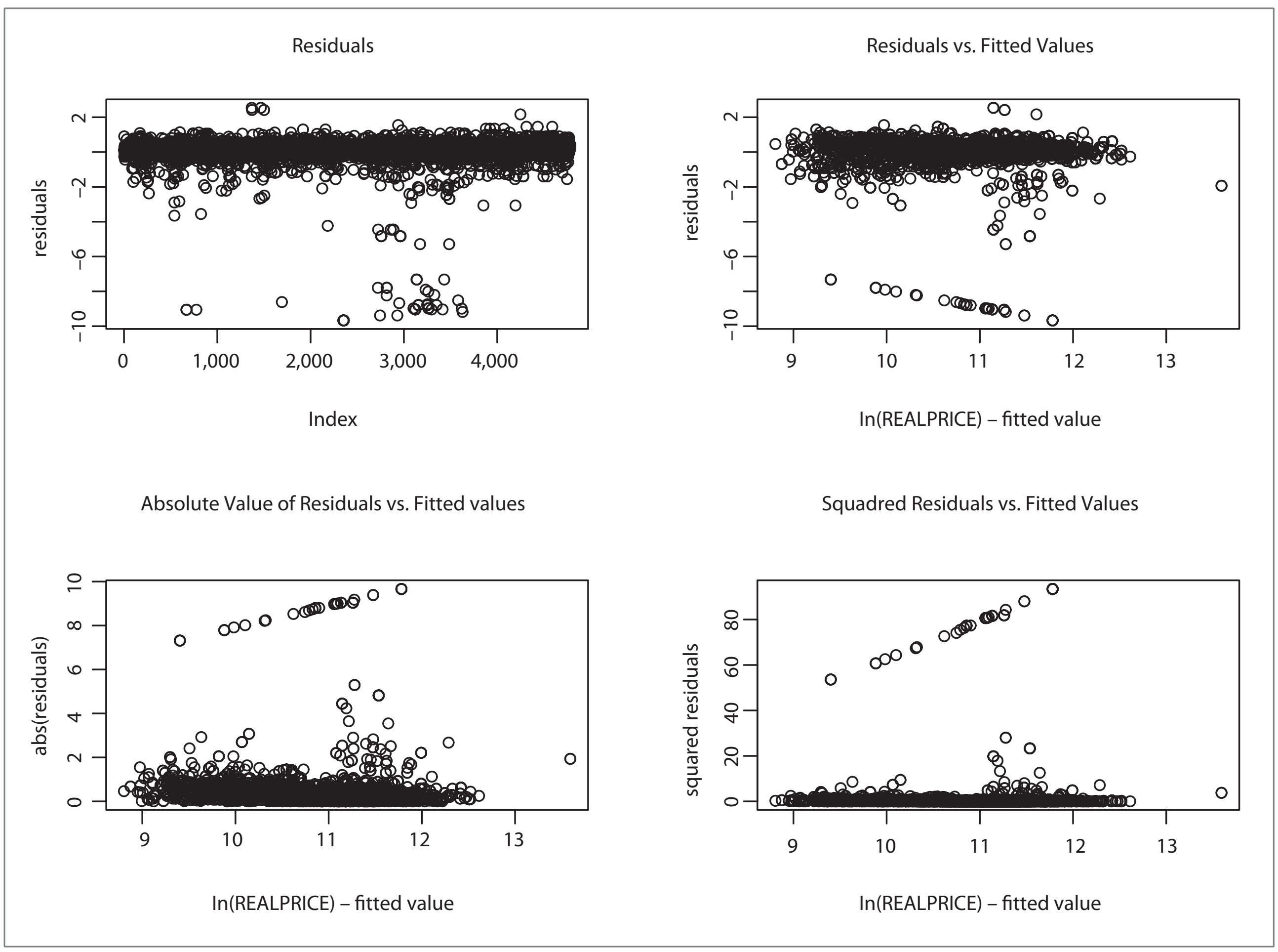


Figure 5: Error variance.

A standard F-test was performed to test H_0: $\pi_{13} = \pi_{14} = 0$ against π_{13} or $\pi_{14} \neq 0$.[7] The residual term ε was added to the structural Equation 2 in order to perform the Hausman test, which shows the corresponding slope of ε to be equal to 134.17 (significant at the 1% level). The fitted value DIST2WATER* of Equation 4 replaced the endogenous variable DIST2WATER in structural Equation 2 in order to obtain 2SLS. The 2SLS model was corrected for heteroscedasticity according to the same procedure used to obtain the robust OLS.

6 Results

Table 3 summarises the results of the study. The standard F-test verified the joint significance of lead and water.[8] The number of stories also seemed to be of economic significance in this model because buyers were willing to pay 35% more for a house with two floors. A location 1 km closer to the army depot resulted in a 2% decrease in the real market price. The marginal reduction in property value based on distance from the depot was approximately $1,484 per km.

Table 3: Results

Variable	WLS model	2SLS model
Lot size	0.005* (0.002)	0.005* (0.002)
House size	1.201‡ (0.140)	1.108‡ (0.133)
House size^2	–0.225‡ (0.038)	–0.196‡ (0.137)
Number of rooms	0.074‡ (0.009)	0.062‡ (0.009)
Number of stories	0.356‡ (0.039)	0.350‡ (0.037)
Pool	0.149‡ (0.035)	0.105‡ (0.037)
Fireplace	0.005 (0.025)	(0.002) (0.023)
Age	–0.009‡ (0.001)	–0.012‡ (0.001)
White households	0.002† (0.001)	0.004‡ (0.001)
Poor households	–0.030‡ (0.005)	–0.200‡ (0.005)
Distance to Anniston Army Depot (incinerator)	0.008‡ (0.003)	0.020‡ (0.004)
Distance to water bodies	–0.172‡ (0.085)	–3.640‡ (0.727)
Pb^{++} (lead concentration)	–0.005 (0.008)	–0.116† (0.051)
Lead-water interaction (lead·water)	/	0.739‡ (0.269)
Intercept	9.059	9.469
R^2	0.247	0.269
adj. R^2	0.245	0.267
Observations	4,783	4,783
F statistic	120	125
Degrees of freedom	4,769	4,768

Notes: *10% significance level, †5% significance level, ‡1% significance level.
The dependent variable is ln(Price); standard errors are shown in parentheses; TOTAL_SQUARE_FT is expressed in thousands of square feet, WHITE_HH and POVERTY_HH are expressed as percentages; DIST2INCIN and DIST2WATER (e.g., from small lakes and open channel flows) are expressed in km and are price distance semi-elasticities; LEADMG is expressed in log form; interaction between lead and water has been reported only for the two-stage procedure.

The environmental variables DIST2INCIN and LEADMG, which are the main focus of this paper, are significant at the 1% and 5% levels, respectively. In monetary terms, the net household benefit derived from the total cleanup of lead would be $1,140. This value was found using a simulation on the 2SLS model setting the variables LEADMG and the interaction between lead and water equal to zero. It is interesting to note that at the qualitative level, because the result does not have any economic significance, it shows a positive relationship between property value and DIST2WATER. This is consistent with the aesthetic value of bodies of water, an interesting natural resources economics topic in Alabama. Table 3 also shows the interaction between water and lead (bodies of water near soil with lead concentration). The direction of the two vectors (property value and DIST2WATER) confirms the desire among home buyers to live far from water sources that might be lightly contaminated by lead because the area is characterized by acid rainfall, which constitutes the optimal condition for lead to contaminate bodies of water. It is unfortunate that more information is not available apart from that which was provided by the EPA and the Anniston Waterworks about the health of bodies of water.

7 Conclusions

This paper examined the impact of lead contamination on property values in Anniston, Alabama. It provided a further extension of application of hedonic modelling within the framework of environmental economics. Apart from the market-based results examined here, it would be possible to improve the analysis by including additional data obtained directly from local residents through questionnaires. This would assist in understanding the risk perceptions related to the army depot as well as perceptions of the health status of the local ecosystem. The confirmation of endogeneity among the explanatory variables was of particular interest in the study. The result was consistent with the findings of other authors such as David M. Brasington and Hite (2008) and Patrick Bayer et al. (2009).

The results of the study show a 2% per km decrease in property value resulting from proximity to an incinerator, a figure that is consistent with the results found by Hanna (2005). The most important finding was that the household benefit from total lead cleanup would be approximately $1,140 per household. The impact of lead on the property value in Anniston is potentially less than the $12 million paid by the EPA since 2002 as an additional cost incurred from lead cleanup. The benefit of cleanup in terms of property values does not account, however, for the potential external benefits: reduced healthcare costs, prevention of lost labour productivity due to the morbidity and decreased mental ability of affected individuals, and increased tax revenues at the local level. It is reasonable to assume that, in addition to the private benefits to property owners, the total cleanup benefits well exceed the costs of the cleanup.

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Notes

[1] LnBlood = 0.0390 + 0.1388(LnSoil) + 0.1210(LnDust) + 0.1715(Income) + 0.1666(Education) + 0.0826(Sex) + 0.1139(Smoke) + 0.1581(Air Conditioning), adjusted $R^2 = 0.2394$

[2] 1 mg/kg = 1 ppm (part per million)

[3] RESET = 16.32, df1 = 12, df2 = 4,758, p-value $< 2.2 \times 10^{-16}$

[4] $REALPRICE = \exp[1.365(TOTAL\_SQUARE\_FT) - 0.155(TOTAL\_SQUARE\_FT)^2 + 9.217]$

[5] $REALPRICE = \exp[1.108(TOTAL\_SQUARE\_FT) - 0.196(TOTAL\_SQUARE\_FT)^2 + 9.722]$

[6] BP = 59.46, df = 13, p-value $= 6.57 \times 10^{-8}$

[7] 2 restrictions, 4,768 degrees of freedom, F = 40, p-value $< 2 \times 10^{-16}$

[8] 2 restrictions, 4,768 degrees of freedom, F = 10.6, p-value $= 6.7 \times 10^{-7}$

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