Resource and Energy Economics 34 (2012) 549–564

Contents lists available at SciVerse ScienceDirect

Resource and Energy Economics

journal homepage: www.elsevier.com/locate/ree

A hedonic analysis of the impact of LUST sites on house prices[☆]

Jeffrey E. Zabel[a,*], Dennis Guignet[b]

[a] Economics Department, Tufts University, 8 Upper Campus Road, Medford, MA 02155, United States
[b] National Center for Environmental Economics, US Environmental Protection Agency, Mail Code 1809 T, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460, United States

ARTICLE INFO

Article history:
Received 14 March 2011
Received in revised form 9 May 2012
Accepted 19 May 2012
Available online 28 May 2012

JEL classification:
Q51
Q53

Keywords:
LUST
Hedonic analysis
Groundwater contamination
Remediation benefits

ABSTRACT

Petroleum from leaking underground storage tanks (LUSTs) can contaminate local soil and surface and groundwater. This can pose health risks to the surrounding population. Focusing on single family home sales from 1996 to 2007 in three Maryland Counties, we use a hedonic house price model and a difference–in-difference approach to estimate the willingness to pay to clean up the LUST sites. Particular attention is given to how property values are affected by leak and cleanup activity at a LUST site, the severity of contamination, the presence of a primary exposure pathway (i.e., private groundwater wells), and publicity surrounding a LUST site. The results suggest that although the typical LUST may not significantly affect nearby property values, more publicized (and more severe) sites can decrease surrounding home values by more than 10%.

Abbreviations: UST, underground storage tank; LUST, leaking underground storage tank; EPA, United States Environmental Protection Agency.

☆ This research was supported by funding from the US Environmental Protection Agency (contract EH08H000849 via Industrial Economics). We thank the Maryland Department of Environment and the National Center for Smart Growth at the University of Maryland for data support. We also thank Anna Alberini, Chip Paterson, Robin Jenkins, Kelly Maguire, and two anonymous referees for useful comments. All views expressed are solely our own, and do not necessarily reflect those of the US EPA, MDE, or National Center for Smart Growth.

* Corresponding author.
E-mail addresses: jeff.zabel@tufts.edu (J.E. Zabel), guignet.dennis@epa.gov (D. Guignet).

0928-7655/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.reseneeco.2012.05.006

1. Introduction

There are over 595,000 gas stations and other commercial and industrial facilities in the United States that store hazardous substances, such as petroleum, in underground tanks.[1] Over time these tanks may leak due to corrosion, cracks, defective piping, and spills during refilling and maintenance activities. Petroleum pollution from leaking underground storage tanks (LUSTs) leaches into the surrounding soil and groundwater and can damage nearby water bodies and ecological systems. As of October 2011, there were over 498,000 known UST releases throughout the United States.[2]

Petroleum by-products are harmful to human health. Vapors can travel upwards through the soil into nearby homes and buildings. This poses acute health risks such as headaches, nausea, and even risks of explosion.[3] Exposure to petroleum by-products over long periods of time increases the risk of several chronic diseases, including cancer, and can affect the kidneys, liver, and nervous system. The primary exposure pathway to humans is through the consumption of contaminated groundwater. Concentration levels of these pollutants in public drinking water are regulated by the US Environmental Protection Agency (EPA), but private groundwater wells are not regulated by the Safe Drinking Water Act and thus routine monitoring is not required.[4]

Due to the potential environmental and human health risks, cleanup of contamination should result in some benefit to nearby residents. This could have significant welfare implications given the large number of LUST sites. Hence, from a policy perspective, it is important to have accurate estimates of these benefits. Given that there is no market for most environmental goods (or bads), economists seek alternative non-market valuation approaches to estimate these benefits. One such approach is the hedonic property value model, where measures of the adverse effects posed by LUST sites are included as explanatory variables. The associated coefficients provide evidence about residents' marginal willingness to pay (MWTP) to clean up the sites.

Previous studies have used hedonic methods to estimate the MWTP to clean up contaminated sites, but none have done so for LUST sites within a framework that allows for the identification of their causal impacts on property values. We believe that we are the first study to do so. We estimate a hedonic house price model using single-family home sales from 1996 to 2007 in three Maryland Counties: Baltimore City, Baltimore, and Frederick. We have information on 219 LUST sites including nearby home sales before and after the discovery of a leak. We also have information on the severity of contamination, the presence of an obvious exposure pathway (i.e., private groundwater wells), and the publicity surrounding a sample of these LUST sites.

Compared to previous analyses, this information allows us to obtain relatively accurate estimates of the impact of LUST sites on property values for three reasons. First, we have information on numerous leaks. We observe substantial variation in the location and timing of leaks being discovered, which mitigates unobserved influences on house prices that are associated with a single site or time period.

Our hedonic models include numerous explanatory variables to control for observable differences across houses and neighborhoods, including either block group or census tract fixed effects to control for unobservable neighborhood characteristics that are correlated with the presence of a LUST site. Careful attention is given to how property values are affected by the severity of contamination, the presence of an obvious exposure pathway, and publicity surrounding a LUST site.

Second, it is crucial to observe house sales over the entire leak contamination and cleanup process. Sales prior to the discovery of a leak help establish a baseline from which one can measure changes in house prices after the leak is discovered. Without this baseline one cannot necessarily make causal inferences about the estimated impacts of LUSTs on home values. We examine how the value of homes in close proximity to a LUST are impacted by the (i) discovery of a leak and subsequent opening of an investigation, (ii) during an active leak investigation and cleanup (if undertaken), and (iii) after closure

---

[1] US EPA, http://www.epa.gov/oust/, accessed October 26, 2011.

[2] US Environmental Protection Agency (EPA), http://www.epa.gov/oust/faqs/faq9a.htm, accessed October 26, 2011.

[3] Maryland Department of Environment (MDE), http://www.mde.state.md.us/assets/document/LRP%20Vapor%20Intrusion%20Guidance(6).pdf, accessed July 16, 2009.

[4] US EPA, http://www.epa.gov/safewater/contaminants/index.html#listmcl, accessed July 16, 2009.

of the leak investigation, at which point cleanup is complete and the LUST is presumably deemed safe by regulators.

Third, we observe sales in areas where no leaks are present and those near registered USTs where a leak does not occur. This allows us to control for background factors that affect the whole housing market. In essence, these are the requirements for the important methodology for identifying the causal impact of potentially endogenous policies or actions known as the "difference–in-difference approach."

Our analysis suggests that the average LUST site is unlikely to have a significant impact on house prices. However, the most publicized (and more contaminated) LUST sites can significantly impact nearby property values by more than 10%.

This paper proceeds as follows. In Section 2, we provide a literature review. In Section 3, we discuss the data used to estimate the hedonic model. In Section 4, we lay out the hedonic framework. In Section 5, we present the results, and conclude in Section 6.

2. Literature review

There is a large literature providing evidence that hazardous waste sites can adversely affect the price of nearby homes, a significant portion of which focuses on Superfund sites. In a survey of the literature, Farber (1998) finds that surrounding residential property values increase, on average, by $3500 for each additional mile away from a hazardous site. Boyle and Kiel (2001) find significant variation in this premium across studies (ranging from $190 to $11,450).

Unfortunately researchers rarely, if ever, observe the perceived risks posed by an environmental disamenity. In the absence of such a measure, the primary identification strategy in most studies relies on the distance of a home from the disamenity. Researchers often posit that contamination and cleanup events represent new public information, which may lead to revisions in risk perceptions, and in turn, a change in the premium for distance from the disamenity (e.g., Kohlhase, 1991; Kiel, 1995; Dale et al., 1996; Kiel and Zabel, 2001). Gayer and Viscusi (2002) focus on this identification strategy by examining the importance of information dissemination. They find that media attention associated with hazardous waste sites leads to an increase in property values, and argue that such information may quell public fears or signal future clean-up.

There are very few studies that specifically examine how groundwater pollution and leaking underground storage tanks affect home values, the majority of which was undertaken well over 10 years ago. Simons et al. (1997; henceforth SBS97) analyze the impact of USTs on residential sales in Cuyahoga County, Ohio in 1992. They considered three types of USTs: non-leaking tanks registered with the State of Ohio, and registered and unregistered LUSTs. SBS97 cite a study by Bowen et al. (1995) that developed a ranking of the toxicity of noxious environmental releases. Based on their analysis, LUSTs are expected to have a very localized impact. SBS97 interpreted this as within sight or within a city block (300 feet). They generated indicator variables for parcels within this distance of the three types of USTs. There were 83 sales within the required distance of an UST; 42 near non-leaking USTs, 24 near leaking but unregistered USTs, and 17 near leaking and registered USTs.

The only indicator that was marginally significant was for leaking and registered USTs. The estimated coefficient indicated that houses near a registered UST that is known to have leaked sold for a discount of $15,152 or 17% of the average sales price in 1992. This result should be viewed with caution since it is based on a small number of sales ($n = 17$) and the model does not control for other potential undesirable land uses that could bias the result. Extending on this analysis, Simons et al. (1999) conducted a limited hedonic study, and found a 14–16% discount for residential properties near and/or with actual contamination from a nearby gas station. Again, caution is warranted in interpreting these results due to the small number of sales among "contaminated" homes ($n = 11$).

More recently, Isakson and Ecker (2010) analyze the effects of 50 USTs and leaks on home values in Cedar Falls, Iowa. In addition to controlling for distance to the nearest UST, they account for the associated risk using an UST-specific risk categorization scheme (i.e., no risk, low risk, and high risk), which is assigned by environmental regulators based on contamination levels, and the presence of receptors within the contamination plume (e.g., water wells, basements, sewers, or surface water). They find that adjacency to a high risk LUST site is associated with about an 11% depreciation in home values, an effect that decays rapidly with distance from the site, and disappears about 1/3rd of a mile away from the LUST.

Based on a few case studies of abandoned industrial properties, Page and Rabinowitz (1993) compare residential properties that depend on private groundwater wells, and find no difference in the price of properties where the groundwater is contaminated with toxic chemicals versus those that are not. Page and Rabinowitz do note that such an analysis is complicated by the unobserved groundwater flows, stating that "neither the direction nor the rate of movement of plumes of toxic chemicals in ground water is predictable without a thorough and costly hydrogeological investigation." (p. 473).

Dotzour (1997) looks at the impact on sales prices of residential properties in an area of Wichita Kansas where groundwater contamination had been discovered. However, few of the properties in the contaminated area used the groundwater for consumption. Dotzour compared the change in average sales price of houses in the contaminated area during the year before and after the contamination announcement to comparable changes in two control areas, and found no significant differences across the three study areas.

Boyle et al. (2010) focus on two towns in Maine, Buxton and Hollis, which in the early 1990s received significant media attention regarding arsenic pollution in groundwater wells. Boyle et al. obtained well-test data, but could not link the results to individual properties. Instead, they construct a "neighborhood" based measure of arsenic, namely the contamination level found by the nearest well-test to exceed the EPA standard of 0.05 mg/L. They find that home prices decline by 0.5–1% for each 0.01 mg/L of arsenic above the EPA standard. This depreciation appears to be temporary since prices rebound within a few years. Boyle et al. speculate this may be due to the availability of in-home water treatment systems or the dissipation of perceived risks once media attention stops.

In summary, there have been numerous studies on the effects of hazardous waste sites on surrounding residential property values but very few have examined the impacts of groundwater contamination and LUSTs on home values. Research on LUSTs and surrounding residential property values have been confined to just two geographic areas (Cuyahoga, Ohio and Cedar Falls, Iowa), and are limited in reliability due to few sales in close proximity of a LUST site. Furthermore, these analyses rely solely on cross-sectional variation of USTs and leaks in order to identify the effect of LUSTs on home values. In this study, however, we exploit spatial *and* temporal variation in a relatively large number of leaks, which allows us to separate the implicit price of leak events from other unobserved spatially correlated influences on home values.

3. Data

Our hedonic analysis focuses on three counties in Maryland: Baltimore City, Baltimore County, and Frederick. First we give a description of the UST sites in these three counties and then provide details of the housing data.

3.1. LUST sites description

Data on the 640 "Remediation Cases" in the study area were obtained from the Maryland Department of Environment's (MDE) Oil Control Program. We focus on the 219 cases where a leak was discovered at an UST facility between 1996 and 2007.[5] Among these LUST investigations, 110 were in Baltimore County, 66 in Baltimore City, and 43 in Frederick County, as shown in Fig. 1. Out of the 219 leak investigations, 138 (63%) could be linked to an UST facility registered with the MDE. The remaining 81 (37%) leak investigations presumably took place at sites where the state (and sometimes the owner) were previously unaware an UST was, or had been, present.

Table 1 provides the breakdown of the openings and closings of leak cases by year. A case is opened when an investigation regarding a potential leak is warranted, which may occur for several reasons,

[5] Among the 640 remediation cases, we focused on the 387 where an investigation was opened between 1996 and 2007. We then eliminated cases with invalid coordinates that correspond to a groundwater pollution investigation that was not linked to a specific LUST, where the 'leak' event was minimal and resulted in nothing that could conceivably affect house prices, and when contamination was the result of something other than a leaking UST.

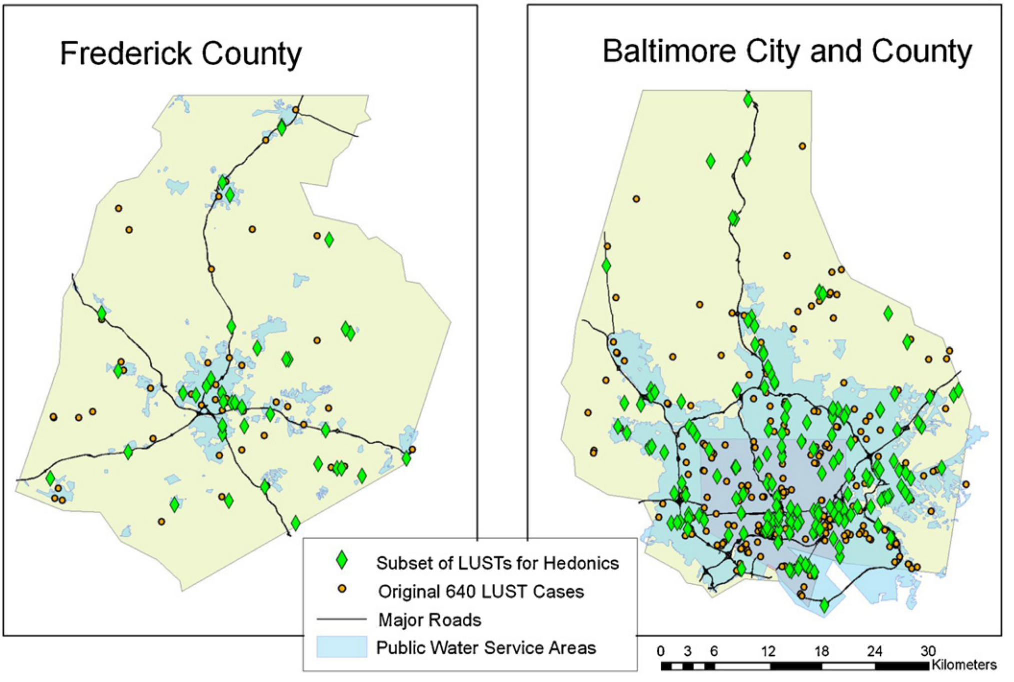

Fig. 1. LUST Investigations in Baltimore City, Baltimore, and Frederick Counties.

including: odor or water taste complaints from nearby residents, issues regarding routine onsite groundwater testing or UST system compliance checks, discrepancies in product inventory records, and if an UST owner reports an issue. MDE investigates opened cases and determines the best course of action, which may or may not include active cleanup. Petroleum products naturally degrade over time, so if there is no public or environmental threat, then ongoing monitoring and natural attenuation is sometimes deemed the best course of action (US EPA, 2004; Khan et al., 2004). We find evidence confirming that pollution plumes migrated to neighboring properties at only 40 (18.4%) of the LUSTs in this study. A case is closed once the LUST is no longer considered an environmental or health threat and active cleanup efforts (if undertaken) are complete. Of these 219 LUST sites, 149 cases were closed

Table 1
Dates of opened and closed LUST cases.

Year	Opened	Closed
1996	21	6
1997	12	11
1998	15	8
1999	14	9
2000	12	11
2001	13	10
2002	11	4
2003	22	13
2004	25	19
2005	41	32
2006	25	19
2007	8	16
2008	0	4
Total	219	149

by 2008; the average leak investigation was open for 1.53 years, the median is 0.57 years, and the maximum is just under 10.5 years.[6] Regarding the leak cases that remained open as of 2008, the average case was open for 4.68 years (the median duration is 3.10 years).

We use information on groundwater testing for petroleum to account for heterogeneity in pollution severity at the individual LUST sites. We focus on groundwater because it is the primary exposure pathway of concern and testing is done much more often (compared to vapor and soil testing). We focus on pollutant concentrations of BTEX; the summation of benzene, toluene, ethylbenzene, and xylenes. This aggregate measure of pollution is commonly reported, though only the individual components are regulated.

The variable we use is BTEX_MAX; the maximum level of BTEX found at any single time and testing location associated with a LUST case. A testing location includes potable wells, as well as monitoring wells at the UST facility and the surrounding area. Testing occurred at only 148 of the 219 LUST sites, so we include a testing indicator in the hedonic model.[7] The mean and median values for BTEX_MAX are 17,818.82 parts per billion (ppb) and 280.75 ppb, respectively, so the distribution is severely skewed right. There are 24 LUSTs where testing revealed no BTEX contamination.

3.2. Sales data

We focus on home sales from 1996 to 2007 in Baltimore, Baltimore City, and Frederick Counties. The transaction data comes from the 1996 to 2007 editions of the MDProperty View CAMA (Computer Assisted Mass Appraisal) Database. Our dataset includes 35,552 sales from Frederick County, 76,968 sales from Baltimore County, and 24,296 sales from Baltimore City County. Summary statistics are given in Table 2.[8]

Although much of the housing stock in Baltimore City consists of townhomes (attached and semi-attached homes) and condominium apartments, we restrict attention to detached single-family homes. We do so for comparability with Baltimore and Frederick Counties, where single-family homes are prevalent, and with previous hedonic studies, which have largely focused on single-family homes. For each home, we have the exact address, latitude and longitude, size of the lot, square footage of the home, age of the home, quality of the structure (fair, average, good, very good), the number of full and half bathrooms, the presence of a garage, the number of floors, and the type of structure (e.g., ranch, split level). Because we have the coordinates of most homes, we also know which census tract and block group they are located in. There are sufficient sales to allow us to include block group (or census tract) fixed effects. These fixed effects allow us to control for all amenities and disamenities that are common to all parcels in the block group (or census tract) and are constant over the time period of our analysis; 1996–2007. We also include distances to local amenities such as lakes, open spaces, commercial districts, and major roads and the number of registered UST facilities (leaking or not) within a 500 meter radius of each home.

We also know whether each house is within the public water service area, or outside this area and presumably reliant on private groundwater wells. All homes in Baltimore City are served by public water, but 32% and 19% of the sales in Frederick and Baltimore Counties were of homes that rely on private groundwater wells for potable water (see Fig. 1).

---

[6] We have information on cleanup dates but they are inconsistent and are reported only semi-annually. Therefore, we do not use this information in this analysis.

[7] Anecdotally, based on personal review of the investigation files, there does not appear to be an explicit testing criterion. Still, testing is more common at sites where there is a potential exposure pathway (groundwater being used) and where there is a population that could be exposed (i.e. nearby homes and businesses). The severity of the LUST event is also a factor in determining whether testing takes place.

[8] Observations were excluded if the sales price was missing, or if lot size or the number of full baths had a value of zero. These are viewed as transcription errors or missing data. We exclude parcels of more than 10 acres, that sold for more than $5 million, or with structures built prior to 1800, that are larger than 8000 square feet, or with more than 10 full baths because these homes are fairly special and are likely to be in a different market than standard parcels. This amounted to less than 1% of the observations. Finally, we excluded observations where the sales price was less than $20,000 since these were likely not to be arms length transactions or were miscoded. Again, this was less than 1% of the observations.

Table 2
Summary statistics for housing data.

Variable	Mean	Std Dev	Minimum	Maximum
Baltimore City County ($n=24,296$)				
Nominal house price (in $1000s)	158.304	147.815	20.06	2520
Real house price (in $1000s, base is 2000)	147.037	133.042	17.441	2306.848
Lot size (acres)	0.205	0.148	0.003	5.280
Living area (1000s of square feet)	1.719	0.779	0.104	7.911
Age of house	71.186	20.389	0	206
Number of full bathrooms	1.579	0.800	1	10
Number of half bathrooms	0.294	0.510	0	5
1 if split foyer 2 levels of living area	0.006	0.080	0	1
1 if split level 3 or more levels of living area	0.007	0.086	0	1
1 if attic or attached garage	0.080	0.271	0	1
1 if dwelling grade is low cost, economy, or fair	0.764	0.424	0	1
Nearest open space in 1000s meters	0.457	0.291	0	1.454
Nearest surface water body in 1000s meters	2.263	1.233	0.027	5.592
Nearest major road in 1000s meters	2.524	1.111	0.017	5.132
Nearest commercial zone in 1000s meters	0.368	0.250	0	1.281
Number of registered tanks within 500 meters	2.537	2.771	0	21
Baltimore County ($n=76,968$)				
Nominal house price (in $1000s)	241.483	182.734	22.575	3300
Real house price (in $1000s, base is 2000)	226.677	161.197	20.280	2740.689
Lot size (acres)	0.512	0.874	0.002	10
Living area (1000s of square feet)	1.789	0.852	0	7.976
Age of house	38.217	26.056	0	206
Number of full bathrooms	1.711	0.738	1	8
Number of half bathrooms	0.550	0.549	0	5
1 if split foyer 2 levels of living area	0.068	0.251	0	1
1 if split level 3 or more levels of living area	0.093	0.290	0	1
1 if attic or attached garage	0.401	0.490	0	1
1 if dwelling grade is low cost, economy, or fair	0.340	0.474	0	1
Nearest open space in 1000s meters	0.540	0.597	0	7.296
Nearest surface water body in 1000s meters	2.470	1.669	0	14.656
Nearest major road in 1000s meters	1.949	1.772	0.001	12.139
Nearest commercial land use in 1000s meters	0.663	0.676	0	6.775
Number of registered tanks within 500 meters	1.174	2.013	0	18
Frederick County ($n=35,552$)				
Nominal house price (in $1000s)	270.828	143.943	25	2901.8
Real house price (in $1000s, base is 2000)	258.237	120.710	26.411	2901.8
Lot size (acres)	0.700	1.129	0.016	10
Living area (1000s of square feet)	1.997	0.801	0.348	7.929
Age of house	20.698	27.249	0	207
Number of full bathrooms	1.962	0.661	1	7
Number of half bathrooms	0.644	0.514	0	5
1 if split foyer 2 levels of living area	0.078	0.269	0	1
1 if split level 3 or more levels of living area	0.053	0.224	0	1
1 if attic or attached garage	0.463	0.499	0	1
1 if dwelling grade is low cost, economy, or fair	0.098	0.297	0	1
Nearest open space in 1000s meters	1.700	1.660	0	10.744
Nearest surface water body in 1000s meters	3.977	2.330	0	12.664
Nearest major road in 1000s meters	2.545	2.450	0.004	17.760
Nearest commercial zone in 1000s meters	0.947	0.987	0	9.697
Number of registered tanks within 500 meters	0.644	1.772	0	16

4. Model development

We now develop the hedonic framework used to calculate the benefits from the cleanup of a nearby LUST site. In particular, we identify causal impacts of LUST sites on property values using the difference–in-difference approach. The framework underlying this approach is comparable to a (randomized) experiment where a treatment is applied to one subset of the sample (the treatment group) and not to the other (the control group). Comparing the outcomes between these two groups, both before and after the treatment, allows us to identify the causal impact of the treatment.

In this case the treatment is the discovery of a leak and the outcome is house prices. In practice, UST facilities are not “randomly assigned” to neighborhoods, and therefore neither are leaks. This suggests that the treatment group may differ from the control group in both observed and unobserved ways. Thus, even after controlling for observable differences in the treatment and control groups (by including explanatory variables in the hedonic house price model), the difference in the change in house prices between these two groups can be due to differences in unobserved neighborhood quality, and not just to the LUST sites. One way we control for potentially confounding influences on house prices is to estimate a neighborhood fixed effects model; this will control for time-invariant neighborhood-specific unobservable factors that affect house prices.

Assume that the price for house i in block group g at time t (P_{igt}) is a log-linear function of house characteristics (H_{it}), neighborhood characteristics (N_{igt}), and a LUST site (LUST). Given the prevalence of LUST sites, we allow for the possibility that price can be affected by multiple sites. The impact of a LUST site is specified as a general function of the distance to the site in meters (D_i) and the perceived (and possibly only potential) health risks associated with the LUST site (R_t). The hedonic model can be expressed as

$$\ln \ P_{igt} = \beta_{0t} + \beta_1 H_{it} + \beta_2 N_{igt} + \sum_{j=1}^{J} LUST(D_{ij}, R_{jt}(D_{ij}); \theta_{jt}) + \nu_g + \tau_t + u_{it} \quad (1)$$

where J is the number of LUST sites that affect the price of home i, ν_g is a block group fixed effect, τ_t is a quarterly time effect, and β_{0t}, β_1, β_2, and θ_{jt} are coefficients to be estimated.

Rosen (1974) showed that these coefficients can be interpreted as the implicit prices for the characteristics of the heterogeneous good, which, in equilibrium, equal the marginal willingness to pay (MWTP) for each characteristic. Since the unit of observation is a house, P_{igt} is the present discounted value (at time t) of the stream of rents from house i. Thus, θ_{jt} will measure the present discounted value at time t of the present and future impact of the LUST site. This can be interpreted as the benefits from cleaning up the site or from living farther away from the site.[9] We include either block group or census tract fixed effects, ν_g, to capture time-invariant unobserved neighborhood quality. The variable ν_g minimizes omitted variables bias that can arise if the unobserved neighborhood characteristics are correlated with LUST.

When estimating θ_{jt} we do not observe the perceived risks associated with a LUST, but we do observe contamination and cleanup events that we presume proxy for publically available information regarding a LUST. If buyers and sellers in the market are aware of these events, then we expect the impact of the proximity to a LUST site on prices to vary based on whether the sale occurred prior to discovery (i.e., before the open date), while the leak case was open, during clean up, or after it was closed. This identification strategy is similar to that used in many hedonic property value studies, especially those focusing on disamenities that remain at a fixed location, such as Superfund sites (e.g., Kohlhase, 1991; Kiel, 1995; Kiel and Zabel, 2001).

We considered several different specifications for the impact of a LUST on house prices; using (a function of) distance to the site and different distance buffers such that the impact is constant within the buffer. We found that the latter worked better given the local nature of the impact, the likely nonlinearities associated with distance, the possibility for multiple LUSTs to affect prices, and the limited number of sales near LUST sites during the three impact periods. A series of variables are created based on 100, 200, and 500 meter buffers, and in some specifications we extend these buffers

[9] We are measuring benefits from non-marginal changes but it is still possible to interpret the changes in house prices as a close approximation to measuring the benefits from the cleanup of LUST sites. First, since these are very local effects, they will not affect the housing market as a whole. Second, since these changes in perceived health risks are not large (as compared to Superfund sites), it is reasonable to assume that marginal benefits are constant and hence total benefits are just marginal benefits times the change in perceived health risks which is what the change in house prices would capture (Bartik, 1988; Freeman, 1993).

up to 2 kilometers. We choose the 100 meter buffer since we expect the impact to be very local and because 100 yards has been used in previous literature (Simons et al., 1997).[10]

The variable PRE_100 is the number of LUST sites within 100 meters of a home where a leak investigation was not yet undertaken as of the time of sale. The variable OPEN_100 is the number of LUST sites within 100 meters of a home where a leak was discovered and an investigation opened as of the time of sale. Finally, the variable CLOSED_100 is the number of LUST sites within 100 meters of a home with a sales date after the closure of the leak.[11]

We define PRE_200, OPEN_200, and CLOSED_200 to be the number of LUST sites within 200 meters of a home with a sale date that is prior to the opening of each qualifying LUST case, during the period each qualifying LUST case is opened, and after the closure of each case, respectively. We define PRE_100_200, OPEN_100_200, and CLOSED_100_200 to be comparable measures of the number of LUST sites between 100 and 200 meters of a parcel. Similarly, we define PRE_200_500, OPEN_200_500, and CLOSED_200_500 to be comparable measures of LUST sites between 200 and 500 meters of a housing parcel.

Our base model is specified as

$$\ln P_{igt} = \beta_{0t} + \beta_1 H_{it} + \beta_2 N_{igt} + \beta_{31}\text{PRE\_}k_{igt} + \beta_{32}\text{OPEN\_}k_{igt} + \beta_{33}\text{CLOSED\_}k_{igt} + v_g + \tau_t + u_{igt},$$
$$k = 100,\ 100\_200,\ 200\_500 \qquad (2)$$

where $\text{PRE\_}k_{igt}$, $\text{OPEN\_}k_{igt}$, and $\text{CLOSED\_}k_{igt}$ are the number of LUST sites in the k buffer of home i where sales date t was prior to the opening date, after the opening date and before the closing date, and on or after the closing date for each qualifying LUST case, respectively.

For the risks of LUST sites to be capitalized into house prices, the potential buyers must know the existence of, and the risks associated with, nearby LUSTs, and hence take this information into consideration when bidding on houses. Generally, the level of information about contaminated site risks that is known by potential buyers is unknown to the researcher. At best, we have ways of gauging this information based on the publicity that the sites receive in the news and by the involvement of local, state, and federal officials in assessing and publicizing the risks of these sites. We investigate this issue is the empirical analysis in Section 5.

Another interesting issue concerns perceived versus actual risk. If the risk is only perceived, it can still cause property values to decline. Similarly, if a LUST case is closed but no active cleanup occurs, this might lead to a rise in property values even though there has not been a decline in actual health risks. Still, there is an economic benefit to local residents since their properties have increased in value (see Gayer and Zabel (2002) for a detailed analysis of objective versus perceived risk).

The impact of PRE_100 will measure the capitalized value of an additional LUST site within 100 meters when a leak has not yet been discovered. This impact could be positive, zero, or negative depending on the average value residents place on living near an additional UST site. The coefficient on PRE_100 establishes a baseline capturing all unobserved influences on house prices in this buffer. If the opening of a LUST case has a negative impact on the MWTP to live near the site then the coefficient for OPEN_100 should be less than the coefficient for PRE_100. The difference in these coefficients is the impact of the opening of the LUST case on MWTP.

Given that we have divided the sales data into periods prior to opening, during the opening, and after the site is closed, we will measure three impacts: OPEN_*k*–PRE_*k*, CLOSED_*k*–PRE_*k* and CLOSED_*k*–OPEN_*k*. In the first two cases, we measure the impact relative to the baseline (i.e., prior to discovery of the leak). OPEN_*k*–PRE_*k* and CLOSED_*k*–PRE_*k* can thus be interpreted as the short-term and long-term treatment effects, respectively. CLOSED_*k*–OPEN_*k* can be interpreted as the difference between the long-term and short-term treatment effects.

Assuming that the opening of the case is information that there are health risks or other negative externalities associated with the LUST site, we expect OPEN_*k*–PRE_*k* to be negative. That is, relative

[10] The subsequent choice of buffers was largely an empirical exercise involving tradeoffs between identifying the set of homes potentially impacted by this extremely localized disamenity, and having a large enough sample to obtain a statistically significant impact, if it exists.

[11] We also estimated models with indicator variables denoting the presence of a LUST in close proximity to a home. These models yield similar results though the fits are not as good as when we include the counts of nearby LUSTS.

to the prior period, we expect that house prices will be lower after the discovery of a leak, which is during the open investigation by MDE. Given that the closing of the case is information that potential health risks and other undesired consequences associated with the LUST have been reduced, we expect CLOSED_*k*–OPEN_*k* to be positive. That is, house prices should be higher during the period after the LUST case is closed and deemed safe by regulators, compared to the period during which it is opened.

The impact CLOSED_*k*–PRE_*k* can be zero if, upon the closure of the leak investigation, it is perceived that negative externalities associated with the leak are mitigated, and if the use of the site is the same as it was prior to opening. The impact CLOSED_*k*–PRE_*k* may also be negative if either the LUST site is still perceived as an environmental disamenity or threat to human health, or if the end-use of the site has changed and is viewed as more of a disamenity. On the other hand, this impact could also be positive if the end-use of the site has changed and is viewed as more of an amenity than the end-use prior to the leak case.

Formally, the impacts corresponding to our base model (Eq. (2)) are[12]:

$$\text{OPEN\_PRE\_}k\text{\_IM} = 100 \cdot (\exp(\beta_{32} - \beta_{31}) - 1)\% \tag{3}$$

$$\text{CLOSED\_PRE\_}k\text{\_IM} = 100 \cdot (\exp(\beta_{33} - \beta_{31}) - 1)\% \tag{4}$$

$$\text{CLOSED\_OPEN\_}k\text{\_IM} = 100 \cdot (\exp(\beta_{33} - \beta_{32}) - 1)\% \tag{5}$$

These impacts are semi-elasticities. That is, these treatment effects are interpreted as the average percent change in house prices.

Our causal interpretation of the impact of LUST sites on house prices relies on two assumptions.[13] The first is that the character of the UST facility does not change in a way where the timing coincides with the opening of a leak investigation. This is a concern, but such events would have to be occurring systematically at many LUSTs throughout the study area and time period in order to bias the estimated price impacts of the average LUST. The second assumption is that homes that sell before and after the discovery of a leak are similar based on *unobserved* characteristics. This rules out the scenario where (unobserved) lower quality homes are more likely to sell after the discovery of a leak since if we do not fully account for this unobserved quality then the estimated impact of a leak may be biased. We investigate these issues in more detail in the online Appendix. Our conclusion is these two assumptions are likely to hold for our analysis.

As previously discussed, our regression model fits in the difference–in-difference framework where the treatment is the discovery of the leak; the date the site is opened. The intensity of the treatment is measured by the contamination level BTEX_MAX; the maximum BTEX reading among LUST sites that were tested in a given distance buffer. This is based on the maximum BTEX contamination level found in the groundwater at any time during the leak investigation, and is meant to proxy the severity of the LUST site. In a second model we allow the impact of LUST sites on home values to vary depending on the severity of the treatment. The details of this model are provided in the online Appendix.

Another important indicator of the impact of LUST sites on house values is whether or not households receive their water from public sources. Homes that are connected to the public water system will likely not be subject to the health risks posed by nearby LUSTs because public water usually comes from non-local sources. In contrast, households that rely on private wells draw their water from the groundwater beneath their home, and are therefore subject to higher *potential* health risks from a LUST in close proximity to their home. Furthermore, private wells are not subject to the routine monitoring and treatment required under the Safe Drinking Water Act.[14] In a third model, we allow the impacts in the three periods to vary by whether water is obtained from a public or private source.[15]

---

[12] The impacts are calculated in this manner because the dependent variable is in logs.

[13] We thank the two anonymous referees for pointing this out.

[14] We emphasize that the presence of this potential exposure pathway does not necessarily mean that exposure occurs, and thus health risks increase. Often LUST pollution does not migrate far enough to reach surrounding private wells. In fact, based on our review of the leak investigations we found evidence confirming that the contamination plume migrated offsite at only 40 (18.4%) of the LUST cases analyzed in this study. Furthermore, if contamination is found in a private well at levels above the regulatory standard, then averting actions can be taken, such as installing a granulated active carbon (GAC) filter or substituting bottled water.

[15] Details are provided in online Appendix.

Table 3
Buffer counts.

Buffer	All homes			Public water			Non-public water		
	All	Tested	cont > 0[a]	All	Tested	cont > 0[a]	All	Tested	cont > 0[a]
Frederick and Baltimore Counties									
PRE_100	155	126	111	138	109	98	17	17	13
OPEN_100	76	72	70	60	56	55	16	16	15
CLOSED_100	77	27	22	74	26	22	3	1	0
PRE_200	720	512	464	634	426	395	86	86	69
OPEN_200	308	262	255	264	218	215	44	44	40
CLOSED_200	421	152	141	402	144	137	19	8	4
PRE_100_200	573	392	359	504	323	303	69	69	56
OPEN_100_200	233	191	186	204	162	160	29	29	26
CLOSED_100_200	344	125	119	328	118	115	16	7	4
PRE_200_500	4190	3372	3038	3724	2926	2681	466	446	357
OPEN_200_500	1696	1380	1359	1549	1233	1224	147	147	135
CLOSED_200_500	2424	1225	1122	2303	1165	1071	121	60	51
Baltimore City County									
PRE_100	34	26	26						
OPEN_100	11	9	9						
CLOSED_100	32	2	2						
PRE_200	179	122	122						
OPEN_200	76	57	57						
CLOSED_200	291	39	39						
PRE_100_200	145	96	96						
OPEN_100_200	65	48	48						
CLOSED_100_200	260	37	37						
PRE_200_500	1245	938	935						
OPEN_200_500	457	302	302						
CLOSED_200_500	2054	538	532						

[a] Number of home sales near LUSTs where testing revealed contamination.

5. Results

The dependent variable for the hedonic regressions is the natural log of house price. Explanatory variables include quarterly time dummies for each year and attributes of the home, including age and its square, the log of lot size (in acres) and its square, the log of the interior area of the home (in square feet) and its square, and dummy variables indicating: 2, 3, and more than 3 full baths, 1 and more than 1 half bath, the presence of an attic or attached garage, whether the house has a split foyer with 2 levels of living area or is a split level with 3 or more levels of living area, and whether the dwelling grade is low cost, economy, or fair. We also include neighborhood characteristics (distance to the nearest major road, open space, surface water body, and commercial district) and a binary variable that indicates the presence of registered UST facilities within 500 meters (leaking or not), and the number of facilities within 500 meters and its square.

For Baltimore and Frederick Counties, we include block group fixed effects. There are not enough sales within block groups in Baltimore City so we include census tract fixed effects instead.

There are fewer sales in proximity to LUST sites in the less dense residential areas in Baltimore and Frederick Counties. Thus, we merge the data for these two counties to maximize the number of observations available to statistically identify the impacts of LUSTs on home values. We feel that while these are probably separate housing markets, they are likely to be fairly similar, so that pooling the data in this fashion will not result in significant bias, particularly since we allow *all* regression coefficients other than those capturing LUST impacts, to vary across the two counties. Running a separate regression for Baltimore City allows us to determine if the impact of LUSTs is different in a more urban market.

The number of observations available to identify each LUST impact is given in Table 3. For some specifications, there are too few observations to identify the 100 meter buffer impacts so we only use 200 and 200–500 meter buffers. An example of where this occurs is in Baltimore and Frederick

Table 4
Results for base hedonic model (Eq. (2)).

Variable/impact	Baltimore/Frederick Counties		Balt City
	(1)	(2)	(3)
100 meter buffer			
PRE	−0.072**		
OPEN	−0.026		
CLOSED	−0.037		
p-Value for joint sig	0.067		
200 meter buffer			
PRE		−0.029***	0.048
OPEN		−0.015	0.024
CLOSED		−0.024	−0.056
p-Value for joint sig		0.025	0.239
100–200 meter buffer			
PRE	−0.019		
OPEN	−0.012		
CLOSED	−0.021		
p-Value for joint sig	0.159		
200–500 meter buffer			
PRE	0.001	0.001	0.028
OPEN	0.016	0.016	0.016
CLOSED	−0.008	−0.008	−0.004
p-Value for joint sig	0.243	0.239	0.518
Percent impacts for 100 meter buffer			
OPEN_PRE	4.713		
CLOSED_PRE	3.613		
CLOSED_OPEN	−1.051		
Percent impacts for 200 meter buffer			
OPEN_PRE		1.396	−2.378
CLOSED_PRE		0.514	−9.836***
CLOSED_OPEN		−0.870	−7.639
Percent impacts for 100–200 meter buffer			
OPEN_PRE	0.704		
CLOSED_PRE	−0.250		
CLOSED_OPEN	−0.947		
Percent impacts for 200–500 meter buffer			
OPEN_PRE	1.523**	1.523**	−1.126
CLOSED_PRE	−0.838	−0.858	−3.112
CLOSED_OPEN	−2.326	−2.346**	−2.009
Observations	112,502	112,502	2429
Number of block groups/tracts	602	602	128
Adjusted *R*-squared	0.788	0.787	0.442
SER	0.205	0.205	0.410

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Counties when identifying separate impacts on the value of homes with public and non-public water sources (there are, however, enough observations to identify the 100 meter buffer impacts when the water source is not differentiated). Another example is for Baltimore City County. For comparison, we also estimate the Baltimore and Frederick Counties model using only the 200 and 200–500 meter buffers (see the online Appendix for regression results).

5.1. Base results

The estimation results for the base model (Eq. (2)) are given in Table 4. We only provide the coefficient estimates for the LUST variables and the associated impacts given in Eq. (3)–(5).[16] The first two

[16] The coefficients for the other variables are generally significant and of the correct sign. The full set of results is available in the online Appendix.

columns display the hedonic regression results for the combined model that includes sales from Baltimore and Frederick Counties. The regression in column 1 measures proximity to a LUST using three distance intervals (100 meters, 100–200 meters, and 200–500 meters), whereas in column 2 proximity is measured using only two buffers (200 meters, and 200–500 meters). This is for comparison to the hedonic results for Baltimore City, which are displayed in column (3). Here distance is measured using two buffers (200 meters, and 200–500 meters) because there were few single-family home sales in Baltimore City within 100 meters of a LUST.[17]

In general, we find no clear evidence that the discovery and cleanup of a leak at the typical LUST site significantly impacts home values. In only one case are the PRE_*k*, OPEN_*k* and CLOSED_*k* variables jointly significant at the five percent level (the 200 meter buffer for Baltimore/Frederick Counties in column 2). The OPEN_PRE_*k*_IM, CLOSED_PRE_*k*_IM, and CLOSED_OPEN_*k*_IM impacts are significant in only a few cases. In one case, the prices of houses within 200 meters of a LUST site in Baltimore City were, on average, 9.8% lower after closure of a leak investigation relative to their value prior to the discovery of a leak. The bulk of this drop occurred when comparing sales after closure to those after discovery, as seen by the CLOSED_OPEN impact of −7.6%. While the negative impact of discovery could have taken time to be capitalized into house prices, typically we would expect the largest drop in prices to occur before the leak investigation is closed. In another instance (the 200–500 meter buffer for Baltimore and Frederick Counties), prices actually rise slightly upon leak discovery and then fall upon closure of the LUST case.

5.2. Alternative specifications

In Section 4, we discussed alternative models that incorporated the severity of the leak and whether homes get their water from the public water system or private groundwater wells. Neither of these models produced results that show that the severity of the leak or the exposure pathway significantly affect house prices. The latter result might not be too surprising given the mitigating behavior that ensues when local wells are found to be contaminated. The details of these results are reported in the online Appendix.

A concern in all hedonic property value models is omitted variables bias, in particular unobserved neighborhood characteristics that may be correlated with explanatory variables of interest. In our analysis we try to minimize such bias by including census track or block group fixed effects (FE). We also account for variation in neighborhood quality within these areas by including measures of the proximity to other amenities and disamenities such as the distance to the nearest major road and open space, and the number of registered non-leaking USTs.

A criticism of this approach is that census tracts and block groups are arbitrary measures of local neighborhoods. Further, such an approach does not allow one to fully capture the variation in neighborhood quality within these areas. An increasingly popular alternative approach for capturing unobserved neighborhood quality is through the use of spatial autoregressive (SAR) models (Anselin, 1988). We estimate several SAR models (details are provided in the online Appendix). Generally, we find no evidence that the SAR model is an improvement over our preferred FE model. Across all the alternative specifications, our overall conclusion remains: that the typical LUST does not appear to adversely impact surrounding property values.

5.3. Results for publicized LUSTs

For LUST impacts to be capitalized into house prices, it is important that the public is aware of the toxic nature and presence of the disamenity. It may well be the case that there is little public information about some of these LUST sites and hence it is not surprising that these sites have little impact on house prices. Some LUST sites have received significantly more publicity than most. Clearly, if any

[17] We also added a buffer for LUST sites within 500 to 1000 meters to determine if there were impacts at this farther distance. These impacts are not statically significant and are very small in magnitude so we did not include this buffer in the results we report in the paper.

sites are going to significantly impact home values it would be this subset.Twenty-three LUST cases in Baltimore and Frederick Counties have received significant public concern. As a result, information on these cases have been posted on the MDE "Oil Control Program Remediation Sites" website, which we use as a proxy for LUST cases for which there is relatively greater knowledge about their existence. We specify a version of the base model that allows for separate effects of these listed LUST sites. Given that the knowledge of these sites is important in determining their impact on house prices, we allow these impacts to evolve over time. We find that coefficients decrease (relative to pre-opening) monotonically the longer the LUST investigations are open, Prices are 5.9% and 8.3% lower for houses that sell between three to six years and more than six years, respectively, after the listed LUST case was opened. Both impacts are significant at the 1% level. Hence, it does appear that prices depreciate more, and this publicity or stigma effect increases, the longer a LUST investigation is open (details and model estimates are provided in the online Appendix).

Finally, we look at the possibility of being able to accurately estimate the impacts of individual sites. Five of the listed sites have sufficient observations to be analyzed individually. We find that prices are impacted differently at different LUST sites, both in magnitude and sign.

Included in this analysis is the Jacksonville Exxon gas station in the city of Phoenix in Baltimore County, which was much larger than the typical LUST site and has received a lot more publicity. In January 2006 over 26,000 gallons of gasoline leaked, affecting residents over a half-mile from the gas station. Six wells were contaminated, and 62 residential wells showed traces of MTBE.[18,19] There are several ongoing lawsuits, and most recently in one suit over $495 million dollars was awarded to compensate 160 families and businesses for losses in property values, emotional distress, and medical monitoring. Furthermore, over $1.5 billion was awarded in punitive damages (Hirsch, 2011).

We estimate a simple version of the base model with binary indicators denoting that a sale was within 1000 meters prior to and after the opening of each of the individual LUST cases. The impact on house prices from the discovery and opening of the Jacksonville Exxon case is a 12.4% decline, which is significant at the 1% level. Given the extent of contamination at the Jacksonville Exxon site, we added a second buffer extending from 1000 to 2000 meters. There was a small drop in house prices of 3.5% (the p-value is 0.0848). This is weak evidence that the impact was felt beyond 1000 meters from the actual site (see the online Appendix for details and model estimation results).

6. Conclusion

As of October 2011, there were over 498,000 known UST releases throughout the United States. Even though potential environmental and human health risks associated with an individual site are often relatively small (compared to those for Superfund sites), the huge number of leaking underground storage tank (LUST) sites suggests that the cleanup and prevention of these leaks may have relatively large welfare implications.

One way to measure the benefits of preventing and cleaning up these leaks is through hedonic property value models. However, identifying the causal impact of LUST sites on property values is difficult because of the very localized nature of the disamenity (and hence small number of sales available for statistical identification), and unobserved local influences on house prices that are correlated with the location of UST facilities and perhaps the occurrence of leaks. Given these complications, identifying the causal impacts of LUST sites requires a rigorous analysis using fairly complex data. For this reason, no study to date has produced plausible estimates of the causal impact of LUST sites on property values. We believe that our analysis is the first to do so.

Our results lead us to generally conclude that the typical LUST site has little impact on the value of homes in close proximity, at least in the three Maryland Counties studied. This is even true for homes that receive their drinking water from private wells.

There are two necessary ingredients in order for house prices to capitalize the risks associated with LUSTs (or other contaminated sites). The first is that potential buyers know the existence of, and the

[18] MTBE (Methyl tertiary butyl ether) is a former gasoline additive and suspected carcinogen (Toccalino, 2005; US EPA, http://www.epa.gov/MTBE/, accessed January 20, 2009).

[19] http://en.wikipedia.org/wiki/Jacksonville,_Maryland, accessed August 18, 2011.

risks associated with, nearby LUSTs, and hence take this information into consideration when bidding on a house. The second is that these informed individuals perceive the LUST as a disamenity.

So, how well aware are Maryland residents of LUST sites? To our understanding, sellers of properties in Maryland are required to notify the buyer of any contamination or underground tanks (leaking or not) that are on their property. However, sellers are not required to disclose information regarding tanks and potential leaks on neighboring properties, and may not even be aware of these issues themselves. Therefore, it is not clear whether people are always aware of a leak and of the cleanup status at each LUST site.[20]

Even if people are aware of a nearby LUST, they might not perceive it as a threat, and perhaps rightfully so. While some LUSTs can result in relatively high contamination levels (the typical LUST site has relatively low levels of contamination) the contamination plumes are often fairly local, and if there are no homes near the plume then there may be minimal risks to surrounding residents. Overall, if people are not aware of the typical LUST or do not perceive it as a threat, then there is no reason to suspect that property values would be impacted. In this case the insignificant estimates from the hedonic regressions would seem reasonably accurate.

Given the importance of information in the capitalization process, we consider a subset of relatively publicized sites where there is substantial concern from the surrounding community. Among these cases, we do find evidence of significant impacts; house values fall by up to 5% when a leak is discovered. We also find that the impact increases the longer a publicized leak investigation has been open; up to 8% for leak cases open for more than six years. This may reflect that it takes time for information about the disamenity to disseminate and the market to respond.

For the most notorious LUST site in our data set; the Jacksonville Exxon gas station in Baltimore County, the prices for homes up to 1 kilometer away dropped by 12.4% on average after the leak was discovered.

Going forward, we cannot over-emphasize the importance of data collection for the accurate estimation of the impact of LUST sites on property values. A major drawback is that the quality and extent of the data collection processes varies considerably from state to state. This makes a detailed analysis of LUST sites at a national scale exceedingly difficult and time consuming. In the case of Maryland, we had to transfer the data to electronic form by hand, which was a tedious process. Clearly, the collection of data on LUSTs and other hazardous waste sites needs to be standardized and put in electronic form before an analysis at the national level can be conducted.

While we believe that our dataset is the most extensive available for the analysis of the impact of LUST sites on property values, it can be improved. In particular, data on plume size and direction, as well as information on the extent of buyers' and sellers' knowledge, is needed to better estimate welfare impacts.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.reseneeco.2012.05.006.

References

Anselin, L., 1988. Spatial Econometrics: Methods and Models. Kluwer Academic Publishers, Dorddrecht.
Bartik, T.J., 1988. Measuring the benefits of amenity improvements in hedonic price models. Land Economics 64 (2), 172–183.
Bowen, W.M., Salling, M.J., Haynes, K.E., Cyran, E.J., 1995. Toward environmental justice: spatial equity in Ohio and Cleveland. Annals of the Association of American Geographers 85 (4), 641–663.
Boyle, K.J., Kuminoff, N.V., Zhang, C., Devanney, M., Bell, K.P., 2010. Does a property-specific environmental health risk create a neighborhood housing price stigma? Arsenic in private well water. Water Resources Research 46 (W03507), 10.
Boyle, M.A., Kiel, K.A., 2001. A survey of house price hedonic studies of the impact of environmental externalities. Journal of Real Estate Literature 9 (2), 117–144.

[20] The Maryland real estate disclosure forms state that it is ultimately the buyer's responsibility to investigate whether any contamination or tanks are on the property to be sold, or elsewhere in the neighborhood. Sellers have no obligation to inform buyers unless they are aware of contamination or tanks that are on (or below) the property being sold.

Dale, L., Murdoch, J.C., Thayer, M.A., Waddell, P.A., 1996. Do property values rebound from environmental stigmas? Evidence from Dallas. Land Economics 75 (2), 311–326.
Dotzour, M., 1997. Groundwater contamination and residential property values. The Appraisal Journal 65 (3), 279–285.
Farber, S., 1998. Undesirable facilities and property values: a summary of empirical studies. Ecological Economics 24, 1–14.
Freeman III, A.M., 1993. The Measurement of Environmental and Resource Values: Theory and Methods. Resources for the Future, Washington, DC.
Gayer, T., Viscusi, K.W., 2002. Housing price responses to newspaper publicity of hazardous waste sites. Resource and Energy Economics 24, 33–51.
Gayer, T., Zabel, J.E., 2002. Perceived versus objective environmental risks: estimating the benefits of cleaning up superfund sites in Woburn, Massachusetts. Mimeo, Tufts University.
Hirsch, A., 2011, July 1. Damages in Balto. Co. leak suit rise to $1.5 billion, Baltimore Sun. <http://www.baltimoresun.com> (accessed 18.08.11).
Isakson, H., Ecker, M.D., 2010. The effect of leaking underground storage tanks on the values of nearby homes. Technical Report. Department of Mathematics, University of Northern Iowa. <http://faculty.cns.uni.edu/~ecker/research.html> (accessed 31.01.11).
Khan, F.I., Husain, T., Hejazi, R., 2004. An overview and analysis of site remediation technologies. Journal of Environmental Management 71, 95–122.
Kiel, K.A., 1995. Measuring the impact of the discovery and cleaning of identified hazardous waste sites on house values. Land Economics 71, 428–435.
Kiel, K.A., Zabel, J.E., 2001. The economic benefits from cleaning up Superfund sites: the case of Woburn Massachusetts. Journal of Real Estate Finance and Economics 22, 163–183.
Kohlhase, J.E., 1991. The impact of toxic waste sites on housing values. Journal of Urban Economics 30 (1), 1–26.
Page, G.W., Rabinowitz, H., 1993. Groundwater contamination: its effects on property values and cities. Journal of the American Planning Association 59 (4), 473–481.
Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy 82, 34–55.
Simons, R.A., Bowen, W.M., Sementelli, A.J., 1997. The effect of underground storage tanks on residential property values in Cuyahoga County, Ohio. Journal of Real Estate Research 14 (1/2), 29–42.
Simons, R.A., Bowen, W., Sementelli, A., 1999. The price and liquidity effects of UST leaks from gas stations on adjacent contaminated property. The Appraisal Journal 67 (2), 186–194.
Toccalino, P., 2005. Human-health effects of MTBE: a literature summary. United States Geological Survey. <http://sd.water.usgs.gov/nawqa/vocns/mtbe_hh_summary.html> (accessed 08.08.09).
US EPA—United States Environmental Protection Agency, 2004. How to evaluate alternative cleanup technologies for underground storage tank sites: a guide for corrective action plan reviewers, EPA 510-R-04-002. <www.epa.gov/oust/pubs/tums.htm> (accessed 23.07.08).