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Abstract:
Actual and perceived damages from environmental disamenities may disrupt a household's otherwise optimal decision of when to sell their home. This study examines this relatively under-investigated topic with an empirical application to petroleum releases from leaking underground storage tanks, like those commonly found at gas stations. The ubiquity and relative homogeneity of this potential disamenity facilitates a difference-in-differences methodology. The results reveal that the optimal timing of home sales is impacted by leak and cleanup events at these disamenities; leading to both selling sooner and delaying a sale, depending on the event, presence of the primary exposure pathway, and the quality of the home. The implications of these results are discussed.

JEL Classification: D62 (Externalities); I18 (Government Policy; Regulations; Public Health); Q51 (Valuation of Environmental Effects); Q53 (Air Pollution; Water Pollution; Noise; Hazardous Waste; Solid Waste; Recycling); R2 (Household Analysis)

Keywords: housing market, property transaction, discrete time duration model, underground storage tank, groundwater contamination

1. Introduction

Local environmental disamenities such as waste disposal sites, brownfields, Superfund sites, industrial factories, and underground storage tanks (UST) that hold hazardous substances, present a variety of undesirable characteristics such as displeasing aesthetics, noise, and odors. Most notably, due to the toxic nature of the materials commonly used, stored, or disposed of, local disamenities also present the possibility of accidental releases that can negatively impact the environment and human health.

The occurrence of accidents at such disamenities may modify a local household's otherwise optimal decision of when to sell their home. That is, homeowners may either move out earlier than planned or are doomed to live close to a local disamenity longer than optimal. A recent drastic example pertains to the 2013 oil pipeline release in Mayflower, Arkansas, United States (US), where over 5,000 barrels of oil were spewed into the surrounding suburban neighborhood (see Eifling and Hirji, 2013). About half of the residents in this middle-income neighborhood put their houses up for sale after the release. This spike in the supply of homes on the market suggests that families were trying to move out earlier than originally anticipated. Those who are staying are not doing so necessarily by choice because, after this incident, many households likely may not have had enough equity to afford a down payment on a home in a different location –which in essence prevents them from re-optimizing their housing bundle in response to the change in environmental quality.

Similar instances exist in the context of numerous other environmental incidents, and may be of particular concern in housing markets hit hard by downswings in boom-bust cycles. Consider the recent water crisis in Flint, Michigan, US, where high lead levels were leaching from aging pipes into the public water supply. Flint was relatively slow to recover after the housing market bust in 2008. Anecdotal evidence suggests that many residents want to leave the city, but are unable to sell their properties for an acceptable price (Netto and Berlinger, 2016). This effect was exacerbated by the recent water crisis, with homes selling for half of what they were worth in 2005 (Vasel, 2016).

This paper studies how the timing of residential sales is impacted by the presence of a leaking underground storage tank (LUST). The primary threat from a LUST is contamination of groundwater –the source of drinking water for nearly half of all Americans (US EPA, 2015).

LUSTs tend to be less high-profile than the examples above. In fact, the media often does not even cover LUSTs because they are a highly localized disamenity and tend to impact only a few households living in very close proximity. However, LUSTs are numerous and widespread. As of the end of FY2015 there were 71,861 LUSTs awaiting to be cleaned up in the U.S alone. The ubiquitous nature of LUSTs not only creates a compelling context to examine the potential impact of environmental disamenities on the timing of households' decisions to sell, but also facilitates a cogent statistical identification strategy.

Two counties in the State of Maryland are used as case studies in this paper –Baltimore and Frederick.[1] The data under analysis encompass a panel of comprehensive information on residential parcels each year from 2000 to 2007 in the two counties. These counties represent an illustrative setting to study the impacts from LUSTs because from 1996 to 2007 petroleum releases were discovered at 106 USTs –that represent 5.4% of the total USTs in the area. News reports suggest homeowners have faced suboptimal home selling times as a consequence of these releases (e.g. Leslie, 2007).

The identification strategy in this paper relies on a quasi-experiment comparing homes located near a LUST (the treated group) and homes near a comparable set of non-leaking USTs (the control group). We examine the effects from three different "treatment" events –the discovery of a release, the ongoing cleanup of a release, and the closure of a leak investigation. The outcome variable under analysis is the annual probability of a sale. This probability is time dependent, meaning that the probability a homeowner sells his/her home varies depending on how long they have lived there, among other things. Discrete duration models are equipped to handle this dependency by modelling the probability of sale conditional upon a household not previously selling their current home (see Harrell, 2015). By exploiting temporal and spatial variation in the discovery of a leak, a spatial difference-in-differences approach is undertaken (Horsch and Lewis, 2009).

The results in this paper suggest that the release of contaminants and subsequent cleanup activities at these LUST sites do impact the timing of sales for homes located within 500 meters of a LUST. These impacts are heterogeneous and vary with the presence of the primary exposure pathway (potable water from private groundwater wells), and quality of the home.

[1] Note that the study excludes Baltimore City, which is considered a separate county from Baltimore County.

The use of duration models to investigate features of the housing market is longstanding (e.g. Zuehlke, 1987; Haurin, 1988; Carrillo and Pope, 2012; De Wit and Van der Klaauw, 2013). However, two features set this study apart from previous applications of duration models to the housing market. First, this study contributes to understand the understudied impacts from local environmental disamenities on the timing of residential transactions. Second, this study does so through a difference-in-differences strategy –which to our knowledge is the first study to do so in this context.

Only two studies have previously used duration models to search for the impacts of environmental disamenities on the selling time of residential properties.[2] Focusing on highway noise, Huang and Palmquist (2001) jointly estimate a hedonic price function and an equation explaining the duration a home is on the market. Their results suggest that highway noise negatively impacts prices, but has no effect on market duration. They speculate that the lack of effects on market duration may be due to two opposing forces. On one hand, a seller has a lower reservation value at higher levels of the disamenity, and is thus more likely to receive an acceptable bid for the home. On the other and, buyers may be reluctant to bid on such a home, and so it is less likely to be sold. We posit that the extent of these opposing forces and the resulting net effects could vary across different types of homes. The heterogeneity in effects found and discussed later in this paper provide support to this argument. Consequently, a model that does not control appropriately for factors driving the heterogeneity of the effects might misleadingly suggest net zeros effects.

Depro and Palmquist (2012) estimate a discrete-time duration model to examine how changes in local ozone impact the probability that a household sells their home. They find that the annual probability of selling is 2.1% higher when ozone concentrations increase by 1 part-per-billion; and 0.5% higher when ozone concentrations decrease by 1 part-per-billion.

The identification strategy in this paper improves upon the strategies implemented in the two studies described above. Huang and Palmquist (2001) focus only on the time a home remains on the market. However, this focus is too narrow given that local disamenities likely impact a homeowner's decision to put their home up for sale. By focusing on all residential parcels,

[2] See Knight (2008) for a review. There is also a small literature estimating these impacts on the transactions of industrial and commercial properties (e.g., Sementelli and Simons, 1997; Simons and Sementelli, 1997; Simons et al., 1999; Howland, 2004).

including houses that were or were not on the market, this study examines the impact of a LUST on the annual probability of a sale. Depro and Palmquist (2012) take a similar approach by examining the probability of sale among all residential parcels. However, given the context of that study, Depro and Palmquist (2012) carry out only a first "difference" in their identification strategy. They observe air pollution levels when a household first bought their home, and then again in each subsequent period, thus dealing with contemporaneous potential confounding effects only argumentatively. For example, air pollution levels may be correlated with traffic noise and other unobserved factors that could confound the results. The difference-in-differences strategy in this paper controls for potential contemporaneous confounding effects by identifying controls based on observable characteristics (see Horsch and Lewis, 2009; and section 4 of this paper for further details).

The next section provides the background on LUSTs. Section 3 provides details on the identification strategy. Section 4 describes the data under analysis. Sections 5 and 6 respectively present results, and conclusions and discussion.

2. Background on LUSTs

In the United States (US) there are around 204,000 industrial and commercial facilities storing petroleum or other hazardous substances in underground storage tanks (US EPA, 2015). Occasionally, these tanks leak due to corrosion, cracks, defective piping, or spills during refilling and maintenance. Leaking contaminants can runoff into nearby waterbodies, and seep into the soil and groundwater. Human exposure to contaminants occurs primarily through consumption of contaminated groundwater (but potentially also through vapor migration and intrusion). Petroleum by-products such as benzene, toluene, ethyl benzene, and xylenes (BTEX) pose health risks, including cancer and adverse effects on the kidneys, liver, and nervous system (US EPA, 2012). Petroleum products can also contain harmful additives, like Methyl tertiary butyl ether (MTBE), a former gasoline additive and suspected carcinogen (Toccalino, 2005).

The current study focuses on Maryland, where all USTs must be registered with the Maryland Department of Environment (MDE). There are a total of 1,954 UST facilities located in the two counties under study –Baltimore and Frederick. From 1996 to 2007, our period of study, petroleum releases were discovered at 106 underground storage tanks located in these counties. A leak can be discovered through a variety of mechanisms, including failure of routine equipment compliance tests; discrepancies during petroleum inventory checks; routine ground water monitoring; and complaints from nearby residents and business regarding vapor odors, or odd tasting/smelling water. In a few cases previous releases have also been discovered when replacing old tanks or when redeveloping a site.[3]

When a leak is discovered, the MDE undertakes an investigation to assess the situation and determine the appropriate actions. MDE may require that cleanup be undertaken or may decide that the LUST is not a threat. Not all LUSTs undergo cleanup efforts. Petroleum products naturally degrade over time, and if there is no foreseeable public or environmental threat then ongoing monitoring and natural attenuation are sometimes deemed the best course of action (US EPA, 2004; Khan et al., 2004). If cleanup is undertaken, it is completed by the time the leak investigation enters the third and final stage – closure of the case, which is reached when the regulatory agency no longer considers the LUST a threat.

Whether actual health risks are present or not, responses in the housing market are driven by buyers' and sellers' perceptions, which in turn depend on public information and awareness. MDE requires a responsible party (usually the underground storage tank owner) to notify the public only in the most severe cases. Notification is only required for "members of the public directly affected by the release and planned corrective action" (COMAR, 26.10.09.08). Under Maryland real estate disclosure laws, sellers are not required to disclose information about nearby pollution unless the for-sale property is actually contaminated. Given these set of rules, although residents and potential buyers are likely aware of nearby gas stations or other UST facilities, they may not necessarily be aware of a leak, should one occur. There may be no obvious signals of contamination, and media attention is usually minimal (and often non-existent). Cleanup activities, on the other hand, can be fairly invasive and yield visual cues making buyers and sellers aware of the disamenity. Cleanup can include removal of the tanks, excavation of contaminated soil, the pumping and treating of groundwater, building concrete caps and containment walls, and on-going testing of offsite wells. These activities can last anywhere from a few days to many years.

[3] Anecdotally, in the two counties examined in this paper, as well as Baltimore City, at least eight of the leak investigations were opened because contamination was found during redevelopment (Guignet, 2013).

3. Identification strategy

The identification strategy in this paper relies on a spatial difference-in-differences (DID) comparison (Horsh and Lewis, 2009). A clear definition of the treatment, treated group, and control group, is essential in all DID comparisons. Treatment in the current context refers to the discovery of a leak and two subsequent events –ongoing clean-up, and closure of a leak investigation due to completion of cleanup. The treated group consists of houses located near to a discovered LUST. The control group consists of houses that are near to a non-leaking UST during the same period. To facilitate a clean quasi-experimental comparison, the empirical models discussed below are estimated using only houses in one of these two groups.

Conventional DID strategies select control observations that are as similar as possible to the treated observations based on characteristics at the individual observation level. In contrast, the *spatial* DID approach selects control and treated groups based on the spatial location of the observations. This spatial approach is critical in accurately identifying the treatment effects of interest. Gas stations and other UST facilities are not randomly assigned over space, and are often strategically placed near busy roads and intersections. Without the proper control group, identification of the treatment effects would be confounded by spatially correlated unobservables such as traffic volume and noise, displeasing aesthetics, crime, and even desirable aspects of having a gas station nearby.

The outcome variable under analysis is the probability that a house is sold in a given year, conditional on the current homeowner not selling the home in previous years. This conditional probability is modeled through a logit model that includes dichotomous variables for each period under analysis. This specification of the outcome variable corresponds to a discrete-time duration model (Jenkins, 1995).

Due to the nonlinearity of the model, the treatment effect is not captured simply by the coefficient associated with the treatment –as it is the case for linear specifications. Instead, the treatment effect in a nonlinear model is the cross difference of the observed outcome minus the cross difference of the potential non-treatment outcome (Puhani, 2012). This difference equals the incremental effect of the treatment on the probability of sale.

The rest of this section provides details on (a) how the outcome variable is modelled through duration analysis; (b) the treatment events under analysis; and (c) estimation of treatment effects when implementing a non-linear DID identification strategy.

a. Duration analysis

Duration analysis deals with the time to the occurrence of an event, and the factors associated with such timing (Cleves et al., 2008). Alternatively, duration analysis models the hazard-based duration –i.e. it is the analysis of time to "failure", or end-of-duration occurrence or spell, given that the duration has lasted a specified length of time. The conditional probability involved in the definition recognizes that the likelihood of ending the spell depends on the length of time elapsed since the start of the spell (Bhat, 2000).

Formally, let T be a discrete variable representing the time at which a home is sold (for notational ease, subscripts denoting each home are excluded). The discrete-time hazard rate h_t for some period *t* is

$$h_t = Pr(T = t|T \geq t; X_t) \tag{1}$$

where X_t is a vector of covariates that may vary with time.

Since in each discrete time interval a home is either sold or not, binary choice specifications naturally arise as an alternative to parameterize equation (1). A general representation of these discrete-time duration models is

$$h_t = F(\propto_t + X_t'\beta) \tag{2}$$

Equation (2) restricts the coefficients of regressors (β) to be constant over time, whereas the intercept $\propto_t$can vary over the discrete periods under analysis. This variation in the intercept is what allows for a hazard model interpretation of the discrete-time specification (Jenkins, 1995).

The usual choices for *F* are the standard normal cumulative density function (cdf) and the logistic cdf. Thus coefficients can be estimated through a panel model (i.e., a stacked probit or logit model) in which a separate intercept is permitted for each duration period (see Jenkins (1995) for details on the derivation of this result).

A logit specification is adopted in this paper[4], and so the probability that the homeowner sells their house in period *t* is estimated as:

$$h_t = \Pr(sold_t = 1 | sold_{t-1} = 0, \ldots, sold_1 = 0; X_t) = \Lambda(\propto_t + X_t'\beta) = \frac{\exp(\propto_t + X_t'\beta)}{1+\exp(\propto_t + X_t'\beta)} \qquad (3)$$

b. Treatments under analysis

This study seeks to identify whether the probability of a home being sold is affected by three different treatment events: the discovery of a leak, the ongoing clean-up process, and the closure of a leak investigation once the State no longer deems the leak a threat.

All residential parcels in this analysis are near an UST that may or may not have leaked during the study period. To account for potential baseline heterogeneity between USTs that do or do not tend to leak, a dummy variable $lust_i$ is included, which equals one if house *i* is within a 500 meter radius of an UST that leaks at some point during the period under analysis (but not necessarily during period *t*), and zero otherwise. That is, $lust_i$ equals one even in cases where a leak has not yet occurred (i.e., the treated group prior to treatment). Inclusion of this variable in the empirical models is advantageous as it serves as a check, and if necessary controls for, any difference in the baseline propensity of sale associated with unobserved characteristics systemic to houses that are close to a LUST.

Three dummy variables define the three treated groups. Let $leaking_{it}$ be a dummy variable that takes value one if house *i* is located near to a leaking UST for which a leak has been discovered but the clean-up process had not been initiated as of period *t*; $leaking_{it}$ takes value zero otherwise. Let $cleanup_{it}$ be a dummy variable that takes value one if house *i* is located near to a leaking UST for which the clean-up process has been initiated and is yet to be completed; $cleanup_{it}$ takes value zero otherwise. Let $completed_{it}$ be a dummy variable that takes value one if house *i* is located near to an UST that has leaked previously but where cleanup (if undertaken) is completed as of period *t*; $completed_{it}$ takes value zero otherwise. To clarify, assume that house *i* is located near to an UST that was leaking during the third year of an observed housing spell and got cleaned-up and the case completed during the fourth year. Then $completed_{it}$ would take value one only starting in the fourth year and for all subsequent years covered by the period under analysis.

[4] Although the results are robust to alternative probit specifications.

The fact that housing spells begin and finish at different years in the study period is an important feature of the data. It allows the effects of spell duration and other broader housing market trends over time to be statistically disentangled. Similarly, since the data include homes near 106 different USTs that leak at different times, the treatment occurs in different years, at different locations, and corresponding to different periods during a housing spell. This spatial and temporal variation in the treatments allow for the inclusion of time fixed effects to absorb overall market trends that may otherwise confound the estimated treatment effects (Hanna and Oliva, 2010). In this way, we aim to minimize any idiosyncratic unobservables that may be correlated with housing sales around an UST.

c. Treatment effects in a non-linear difference-in-differences model

Given the definition of the treatment variables described in the previous subsection, the econometric specifications of equation (3) can be expressed as follows

$$h_t = \Lambda(\propto_t + \beta_l lust_i + \gamma_1 leaking_{it} + \gamma_2 cleanup_{it} + \gamma_3 completed_{it} + X_t'\beta_x) \quad (4)$$

In a linear DID model, γ_1 (or γ_2, γ_3) reflects the treatment effect. However, in a non-linear DID model with a strictly monotonic transformation function –such as the one described by equation (4) — the sign of γ_1 (or γ_2, γ_3) captures the direction of the effect but by itself does not provide information on the magnitude of the effect. Instead, the treatment effect equals the incremental effect of the interaction term coefficient on the hazard rate (Puhani, 2012).

That is, the treatment effect of, for instance, the event of a leak being discovered in period *t* of a housing spell $(\mathrm{TE}_1(t))$ is calculated as

$$TE_1(t) = \Lambda(\propto_t + \beta_l lust_i + \gamma_1 + X_t'\beta_x) - \Lambda(\propto_t + \beta_l lust_i + X_t'\beta_x) \quad (5)$$

Similarly, the corresponding treatment effects for *cleanup* and *completion* are calculated as

$$TE_2(t) = \Lambda(\propto_t + \beta_l lust_i + \gamma_2 + X_t'\beta_x) - \Lambda(\propto_t + \beta_l lust_i + X_t'\beta_x) \quad (6)$$

$$TE_3(t) = \Lambda(\propto_t + \beta_l lust_i + \gamma_3 + X_t'\beta_x) - \Lambda(\propto_t + \beta_l lust_i + X_t'\beta_x) \quad (7)$$

4. Data

The data used to estimate the empirical models is based on a combination of several datasets, including a database of all residential parcels and transactions for Baltimore and Frederick Counties in Maryland, US; and databases of all USTs registered with the state of Maryland and all leak investigations conducted by the MDE.

A panel dataset was constructed where each observation corresponds to a single-family home in a given year. There are 182,078 single-family homes, covering the years 2000 to 2007. Given the localized nature of the disamenity suggested by previous hedonic property value studies (Zabel and Guignet, 2012; Simons et al., 1997), focus is drawn to the 81,179 single-family homes within 500 meters of a registered UST. Since new UST facilities are built over time, the panel is unbalanced, with a total of n=648,815 observations. Focusing on this subset of single-family homes, 28% of homes sold at least once during this period. Approximately 9% and 27% of the homes in Baltimore and Frederick Counties, respectively, are in areas served by private wells.

A housing spell is defined as the period in which the same household owns the home, and the duration of the spell consists of the number of years from when a household first buys the home until they decide to sell (or until the end of the study period). The 81,179 single-family homes examined in this study correspond to 105,399 housing spells. Since we only observe transactions starting in the year 2000, 77% of the housing spells are left-censored, meaning that we do not observe the starting period of the spell. We deal with these censored spells by declaring the year 2000 (the first year of our study period) as the beginning of the spell. These left-censored spells are then accounted for in the empirical analysis by including a *censored* dummy, equal to one if the observation corresponds to a left-censored housing spell; and zero otherwise.[5] The full spell duration is observed for 24,364 (or 23%) of the housing spells. Among this set of non-left-censored housing spells we see that the mean spell duration is just under four years.

Descriptive statistics of the single-family homes are presented in Table 1. The average home has an interior size of about 1,600 square feet, is 1.5 stories, 55 years in age, and is located 13 kilometers from the nearest central business district.

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[5] We find our later empirical results are robust if we simply exclude observations corresponding to these left-censored spells, as done by Depro and Palmquist (2012).

Figure **1** shows the annual transaction rate for each county from 2000 to 2007. There is a bit more fluctuation in the more rural county of Frederick, but the rates are fairly similar across counties, ranging from 2.5% to 5.5% of homes being sold in a given year. There is a similar trend over time, including the market downturn after 2005. As of 2007, 11,647 of the homes in the sample (14.4%) were within 500 meters of an ongoing or closed leak investigation.

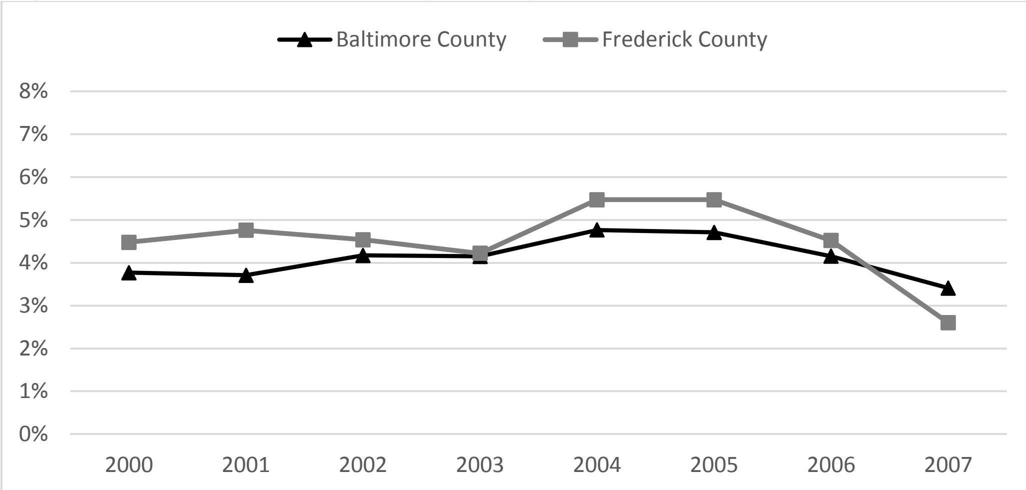
Table 1. Attributes of Single-Family Homes (2007).

Variable	Obs	Mean	Std. Dev.	Min	Max
interior square footage	81,179	1,598	707	286	18,156
lot size (acres)	81,154	0.416	1.014	0.002	152.840
number full baths	81,179	1.54	0.69	0	21
number half baths	81,179	0.41	0.54	0	4
porch size (sqft)	71,687	304	225	1	4352
number of fireplaces	35,004	1.15	0.44	1	8
basement (dummy)	81,179	0.74	0.44	0	1
number of stories	81,179	1.51	0.45	1	3
attached garage (dummy)	81,179	0.27	0.45	0	1
low quality construction[a]	81,156	0.006	0.075	0	1
average quality construction[a]	81,156	0.886	0.318	0	1
good quality construction[a]	81,156	0.105	0.307	0	1
high quality construction[a]	81,156	0.003	0.053	0	1
age of home (years)	81,141	55	24	1	278
in private groundwater well area (dummy)	81,179	0.1183	0.3230	0	1
distance to central business district (kilometers)[b]	81,179	13.33	5.94	0.17	48.20
meters to nearest public open space (meters)	81,179	561	596	0	7784
distance to nearest commercial zone (meters)	81,179	387	509	0	8472
distance to nearest major road (meters)	81,179	684	802	0	8759
number of USTs within 500 meters	81,179	3.12	2.83	1	25

a. Binary indicator variables denoting construction quality based on classifications by tax assessors.
b. Central business district defined as Baltimore's inner harbor for Baltimore County and the City of Frederick for Frederick County.

The MDE provided data on all USTs registered with the State. Attention is restricted to the 1,952 registered UST facilities in Baltimore (1,493) and Frederick (459) Counties. The average facility has three tanks, with a total capacity of 16,864 gallons. Among the facilities where the site use is listed, the majority are gas stations. Most facilities are in areas connected to the public water system (78%), but there are 426 UST sites in areas served by private wells.

Figure 1. Sale Rates over Time by County.

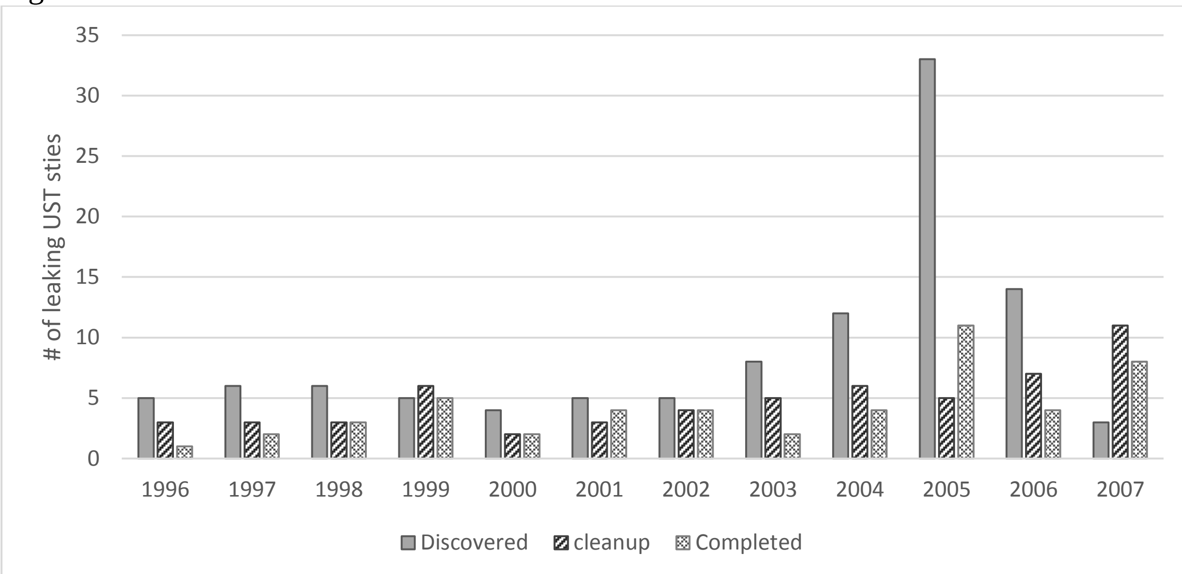


The percent of single-family homes sold each year in Baltimore and Frederick counties, Maryland, USA.

From 1996 to 2007, petroleum releases were discovered at 106 (5.4%) of the registered UST facilities. About 32% of leaks occurred in areas where surrounding homes rely on private wells for their drinking water. At 23 of these sites there was evidence in the MDE investigation files confirming that contamination migrated to neighboring properties. As of 2007, active cleanup efforts had been undertaken at 44 of the LUST sites (41.5%).[6] Figure 2 displays the number of leaks discovered each year, as well as the number of sites where cleanup was initiated, and where cleanup was completed and the investigation closed. The discovery and subsequent events are fairly well distributed across the study period. The only exception is a spike in leaks discovered around 2005, which corresponds to the implementation of more stringent monitoring and testing requirements in the State (COMAR 26.10.02.03-4). Overall the treatment events are well distributed both spatially and temporally, lending support to the spatial DID approach by minimizing the influence of unobserved idiosyncratic biases associated with a single time period or location.

[6] See Guignet (2013) for details on the UST and petroleum release data.

Figure 2. Treatment Events over Time.



The number of leaking underground storage tank (LUST) sites where a leak was discovered, cleanup initiated, and cleanup completed and the leak investigation closed in each year.

5. Results

Several variants of the hazard function in equation (4) were estimated using the panel of 81,179 single-family homes that are within 500 meters of a UST facility. The dependent variable in all models is a dummy variable denoting whether the home was sold in a given year. All the parcel, house structure, and locational covariates presented in Table 1 are included on the right-hand side of the regression models, as are year fixed effects to control for broader housing market trends, and dummy variables denoting the duration period of the housing spell.[7]

Table 2 reports the parameter estimates of primary interest from two specifications. Model 1.A refers to the base logit specification, and Model 1.B builds upon that by including interaction terms testing for heterogeneous effects –differentiating homes based on whether they are served by public water or rely on private groundwater wells. This differentiation is carried out based on the fact that environmental disamenities can impact households differently depending on the presence

[7] For some housing characteristics companion missing value indicators are included and missing values are recoded as zero (see Table 1). Interior square footage and parcel size enter the model in natural log form, and the inverse of distance to the nearest central business district is used. See Table A.1 in the Appendix for the full set of coefficient estimates.

of a primary exposure pathway (e.g., Guignet, 2012, 2013; Muehlenbachs et al., 2015), in this case private groundwater wells being the source of potable water.

Table 2. Discrete-time Duration Models (Annual Probability of a Sale).

VARIABLES	Full Sample Logit (1.A)	Full Sample Logit (1.B)[a]	
		Public Water	**Private Well**
# of USTs within 0-500 m	0.0041*	0.0039	0.0057
	(0.002)	(0.002)	(0.024)
LUST within 500m	-0.0108	-0.0164	-0.0016
	(0.026)	(0.027)	(0.086)
× leak discovered	0.1105**	0.1537***	-0.1186
	(0.044)	(0.047)	(0.128)
× ongoing cleanup	-0.1076*	-0.0712	-0.7144**
	(0.063)	(0.064)	(0.305)
× cleanup completion	0.0493	0.0655	-0.0729
	(0.038)	(0.040)	(0.140)
Period 2	0.2539***	0.2539***	
	(0.043)	(0.043)	
Period 3	0.4771***	0.4771***	
	(0.045)	(0.045)	
Period 4	0.4046***	0.4045***	
	(0.050)	(0.050)	
Period 5	0.2700***	0.2697***	
	(0.057)	(0.057)	
Period 6	0.1401**	0.1399**	
	(0.062)	(0.062)	
Period 7	0.0033	0.0031	
	(0.069)	(0.069)	
Period 8	-0.0197	-0.0197	
	(0.077)	(0.077)	
Censored	-0.0990***	-0.0984***	
	(0.035)	(0.035)	
Observations	648,815	648,815	

*** p<0.01, ** p<0.05, * p<0.1.
Std errors are in parentheses, clustered for same parcel for all years.
[a] Model 1.B is estimated on the full sample by interacting all treatment-related variables with dummy variables denoting two mutually exclusive groups– one denoting homes that rely on private wells to obtain water, and the other denoting homes connected to the public water system.

Table 2 reports the parameter estimates associated with (i) dummy variables denoting the period of the spell; (ii) the variables corresponding to the presence (and density) of local USTs; and (iii) treatment variables reflecting the discovery of a leak, the ongoing clean-up process, and the closure of a leak investigation and completion of cleanup (when undertaken).

Discussion of estimates reported in table 2 focuses on the statistical significance and sign as initial indicators of the effects under investigation. Three features are highlighted across the two specifications. First, estimates in both specifications suggest no differences in the baseline propensity of sale –which is inferred from the lack of statistical significance of the parameter associated with the dummy denoting the presence of a LUST within 500 meters. This variable includes LUST sites where the leak may not have yet been discovered (or even occurred), and so the corresponding coefficient captures the baseline propensity of a sale among the treated group prior to treatment. The lack of a statistical difference in this baseline propensity of a sale bolsters our assumption that homes close to a non-leaking UST are not systematically different than homes close to a LUST before the leak is discovered. In other words, the treated group prior to treatment is similar to the control group.

The second feature of table 2 refers to the significance and opposite direction of the effects from the events under investigation. According to model 1.A, the discovery of a leak has a statistically significant and positive effect on the annual probability that a home is sold; ongoing cleanup negatively impacts the probability of a sale; and the completion of cleanup has no statistically significant effects.[8] We discuss the implications of these results in a moment.

The third feature of interest refers to the heterogeneity in the effects that are uncovered by model 1.B –while the positive effect from the discovery of a leak holds only for homes served by public water, the negative effect from the ongoing cleanup holds only for homes that rely on private groundwater wells.

Table 3 reports estimates of the treatment effects –calculated as described in equations (5) to (7). These effects are estimated for an "average" home, which corresponds to a home in the fourth year

[8] In some cases a house can be within 500 meters of up to three UST releases. This is not surprising given that release investigations at one site can lead to further investigations at other nearby USTs. The results are robust to the inclusion of count variables instead of dummy variables denoting the treatment events. In only a few cases (0.20%) did a home simultaneously experience different treatment events at different UST sites in a given year.

of a spell (the mean duration among the non-censored spells). According to model 1.A, the average effect from the discovery of a leak is an increase of 0.58 percentage points in the annual probability of sale. That is, when a leak is discovered near a home that has not been sold for four years, this home experiences a 0.58 percentage points increase in its probability of sale. This increase in probability is measured with respect to the probability of sale of a home with the same house structure and location characteristics, including being near a registered UST, but where no leak has occurred. This slight increase in the probability of a sale suggests that some households are re-optimizing their housing bundle in response to the disamenity. Ongoing cleanup activities have the opposite effect. According to model 1.A, an ongoing cleanup decreases the probability of sale by 0.51 percentage points (relative to the counterfactual home where no leak has occurred). In line with signs and significance reported in table 2, cleanup completion and closure of the leak investigation has no significant impact on the probability of sale.

Table 3. Treatment Effects for "Average" Parcel (in period 4).

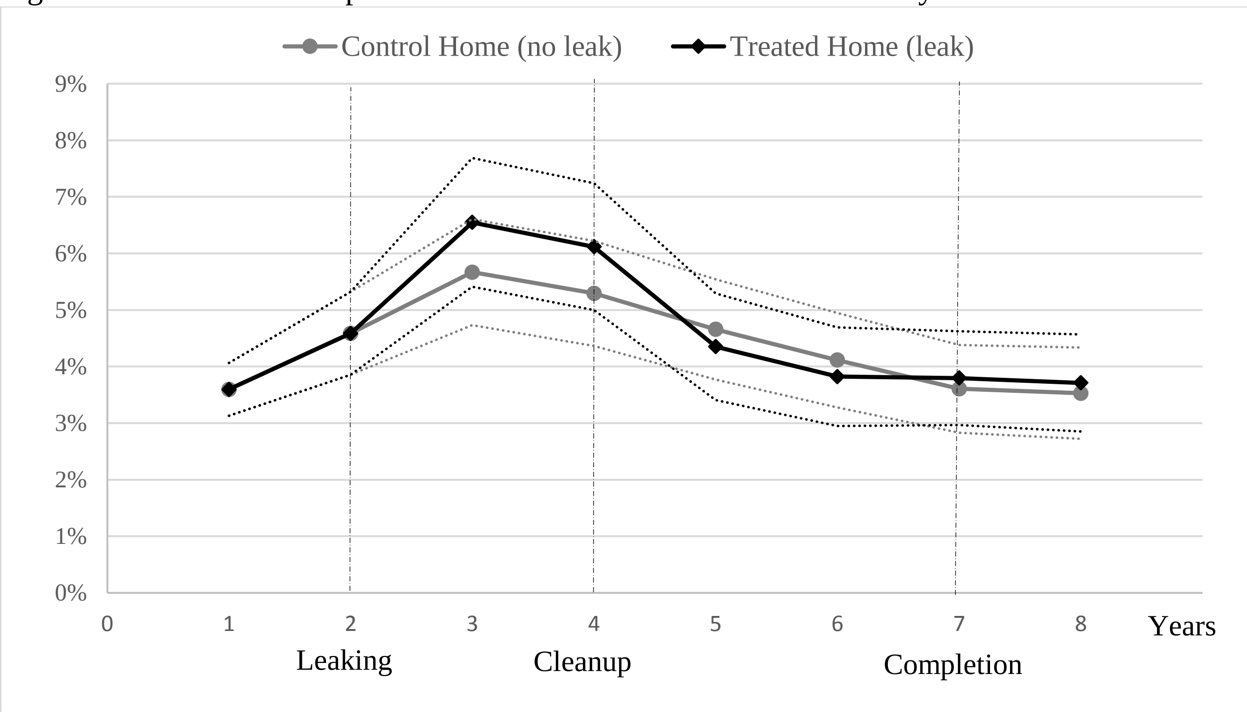
	Full Sample Logit (1.A)	Full Sample Logit (1.B)	
Treatment Effects		**Public Water**	**Well Water**
Leak discovered	0.0058**	0.0083***	-0.0054
	(0.0024)	(0.0027)	(0.0058)
Ongoing cleanup	-0.0051*	-0.0035	-0.0252***
	(0.0029)	(0.0031)	(0.0085)
Cleanup completion	0.0025	0.0034	-0.0034
	(0.0020)	(0.0021)	(0.0064)

*** p<0.01, ** p<0.05, * p<0.1. Std errors are in parentheses, clustered for same parcel over all years.

When exploring the heterogeneity in the impacts through model 1.B, it becomes apparent that the effects from the treatment events vary depending on the presence of the primary exposure pathway (i.e., whether the homes rely on private groundwater wells, as opposed to being connected to the public water system).

Figures 3 and 4 illustrate the effects that we have just discussed. First turning to figure 3, the grey line illustrates the evolution of the probability of sale of a home near to a non-leaking UST (the control group), and the black line illustrates the evolution of the probability of sale of a home near to a LUST (the treated group). These homes are exactly the same (conditional on observed characteristics) and both are connected to the public water system. The only difference is that, for purposes of this illustration, a leak is discovered at a LUST in period 3 near the "treated" home, and then cleanup and closure of the investigation take place in subsequent periods (periods 4 and 7, respectively).

Figure 3. Illustrative Example for a Home Connected to Public Water System.



The evolution of the annual probability of sale for an illustrative "average" home in a given year. Estimates based on model 1.B for a home that is connected to the public water system.

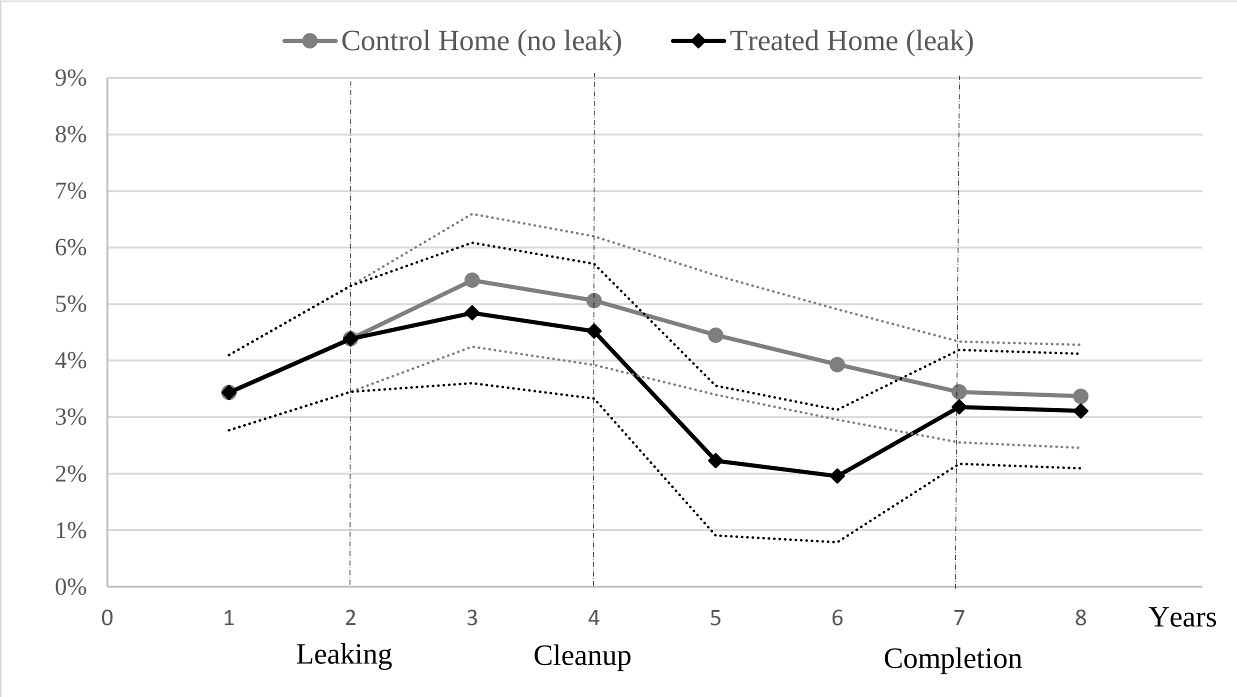
The trend of the probability of sale for the control home is initially increasing and then, after the third period, gradually decreases. Had the empirical model not taken into account the time dependence of the probability of sale, the probability of sale of the control and treated homes would have been assumed constant across periods –with the consequent loss in richness of the story that can be described.

The treated home follows a similar trend as the control home. However, the annual probability of sale of the home becomes slightly higher during the periods between the discovery of a leak and the launch of the cleanup; about 0.88 percentage points in period 3. Even when the probability of sale decreases for both homes after the third period, the probability of sale of the treated home remains higher, about 0.83 percentage points in period 4. These effects are sizable. Consider that the probability of reference is around 5.2% --i.e. the probability that the control home is sold in period 4. Thus a 0.83 percentage point increase represents a 16% increase relative to the reference probability in period 4. Consistent with the lack of effects from ongoing cleanup and case closure, the evolution of the probability of sale for both public water homes is similar once the cleanup process is initiated.

Now turning to figure 4, which presents the same treated and control home comparison, but where these "average" homes are now located in an area where the potable water is supplied by a private groundwater well, making the water potentially susceptible to contamination. A similar story can be told, where the annual probability of sale for the control home initially increases, but then gradually decreases after the third year a household is living in their home, and then leveling off after the seventh year. Comparing this to the treated home, we see that, in contrast to homes on public water, the discovery of a leak has no statistically significant impact on the annual probability of sale. One potential explanation for this contrasting result is that households connected to the public water system do not have trouble selling their current home and re-optimizing their housing bundle. Households connected to public water are less susceptible to exposure from a nearby LUST, and buyers in the market may not necessarily be informed since there is often no direct threat. In contrast, households in homes that rely on private groundwater wells, and hence where the primary potential exposure pathway is present, may not be as easily able to sell their current home and re-optimize their housing bundle in response to the disamenity.

Consistent with this point, we see in figure 4 that, once the cleanup process is initiated, the probability of sale drops fairly drastically, by about 2.2 percentage points (compared to the control home), corresponding to a 50% reduction in the probability of sale. This decrease in sales activity rebounds once the cleanup is completed, to the point that there is no statistical difference between the treated and control homes.

Figure 4. Illustrative Example for Home with Private Well.



The evolution of the annual probability of sale for an illustrative "average" home in a given year. Estimates based on model 1.B for a home that is connected to the public water system.

The fact that local housing market activity seems to slow dramatically during cleanup suggests that the corresponding cleanup activities (e.g., tank removal, excavation of contaminated soil, groundwater treatment, etc.) may serve as visual cues that make buyers and sellers aware of contamination issues and/or cause them to perceive the risks as more severe (Dale et al., 1999; Messer et al, 2006), potentially leading to a public stigma towards the neighborhood (Gregory and Scatterfield, 2002). Residents may also find cleanup efforts bothersome and aesthetically displeasing (Weber et al., 2001). In either case, these cleanup activities seem to deter buyers from looking at nearby homes and/or discourage sellers from entering the market, at least until the situation is resolved and such visual cues cease.

Given the seeming importance of households' awareness of the disamenity and the information aiding in their formation of perceived risks, we next examine how households being explicitly informed may impact the annual probability of a sale. In a previous hedonic study of these data, Guignet (2013) found that transaction prices were 11% lower among homes where the private well was tested. At these homes households were most at risk to exposure, and were formally notified of a nearby release and contamination in their private well. Focusing just on homes relying on private wells, the specifications reported in table 2 were re-estimated with additional dummy variables indicating (i) whether the private well at each home was tested for contamination; and (ii) whether the test results revealed contamination levels above zero, or above the regulatory standards in Maryland. The results are available in the appendix (table A2). In short, estimates suggest that notification and private well testing (and actual contamination levels) have no effect on the probability of sale.

We further examine heterogeneity in the treatment effects by categorizing homes as either high or low quality. The models reported in table 2 are re-estimated separately with just observations corresponding to homes that rely on public water, and then just homes that use private groundwater wells. Additional interaction terms are included to allow the treatment effects to differ across high versus low-quality homes, these dummy variables are defined based on construction quality ratings from tax assessors.[9]

The estimated treatment effects are shown in Table 4.[10] The results suggest that homes with public water (model 3.A) still face an increase of about 0.81 percentage points in the annual probability of a sale when a leak is discovered, but this is only among lower quality homes. Among high quality public water homes there is a statistically insignificant increase upon the discovery of the leak, followed by a 2.1 percentage point decrease in the annual probability of sale. This is similar to the previous pattern revealed among homes with private wells. Even though the primary exposure pathway is not present among these high quality public water homes, perhaps homeowners hold out until the situation is resolved in order to avoid taking a hit on the transaction price for their relatively high quality asset.

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[9] The below results are robust to alternative definitions of high versus low quality homes, including those based on where a home falls within the distribution of assessed values in a given year.
[10] The regression coefficient estimates are available in the appendix (table A3).

Table 4. Treatment Effects for "Average" Parcel: Heterogeneity by Home Quality and Water Source (in period 4).

	Public Water Homes Logit[a] (3.A)		Private Wells Homes Logit[a] (3.B)	
	High Quality	**Low Quality**	**High Quality**	**Low Quality**
Treatment Effects				
Leak discovered	0.0054	0.0081***	-0.0171	-0.0020
	(0.0230)	(0.0028)	(0.0144)	(0.0058)
Ongoing cleanup	-0.0207**	-0.0015	-0.0069	-0.0260**
	(0.0091)	(0.0033)	(0.0273)	(0.0105)
Cleanup completion	0.0103	0.0033	0.0071	-0.0026
	(0.0099)	(0.0022)	(0.0312)	(0.0064)

*** p<0.01, ** p<0.05, * p<0.1. Std errors are in parentheses, clustered for same parcel over all years. Model 3.A estimated based on subsample of single-family homes connected to the public water system, and model 3.B estimated based on subsample of single-family homes that rely on private groundwater wells. Low end homes defined by home quality rated as "low" or "average" by tax assessors, and higher end homes are those rated "good" or "high." Regression coefficient estimates presented in table A3 of appendix.

In contrast to earlier results, model 3.B reveals that high quality homes using private groundwater wells do not see any statistically significant impacts on the probability of sale. The results demonstrate that the decrease in the probability of sale is experienced primarily among relatively low quality homes, suggesting a 2.6 percentage point decrease. Considering that the average counterfactual low quality home that uses a private well has a 4.67% probability of selling in period 4, this implies that the probability of sale is reduced by 55%. The fact that lower quality homes, which likely correspond to relatively low income households, are over half as likely to sell during these cleanup activities suggests the potential for environmental justice issues that may warrant further attention.

6. Conclusions and Discussion

Results reported in this paper are illustrative of the heterogeneity of impacts from a leaking underground storage tank (LUST) on the timing of residential sales. Given that the primary potential threat from a LUST is contamination of groundwater, we have tested and found heterogeneity of impacts depending on the presence of this primary exposure pathway. Homes connected to the public water system experience an increase in their probability of sale when a leak is discovered but, once the clean-up process is initiated, the probability returns to similar levels as those faced by a home near to a non-leaking UST. The temporary increase in the annual probability of sale is about a 16% increase relative to the probability of sale faced by the control group. Homes that rely on a private well experience a decrease in the probability of sale only when the cleanup of contamination is underway. Once the cleanup process is completed, the probability of a sale reverts back to levels similar to those faced by the counterfactual home near to a non-leaking UST. This temporary decrease in the annual probability represents a fairly large reduction of 50% in the probability of sale relative to the control group.

The heterogeneity of these effects deserves further discussion. Homeowners relying on a public water system may be less constrained in selling their home and re-optimizing their housing bundle, in comparison to owners of homes with private wells. We believe this is likely behind the different patterns of reaction reported in this study. Households living in homes connected to the public water system are less susceptible to exposure from a nearby LUST (since the primary exposure pathway is not present), and buyers in the market may not necessarily be informed since there is often no direct threat. In contrast, households in homes that rely on private groundwater wells, and hence where the primary potential exposure pathway is present, may not be as easily able to sell their current home and re-optimize their housing bundle in response to the disamenity.

Further investigation has revealed that the negative effect of cleanup on the probability of sale is experienced primarily among lower quality homes that rely on private groundwater wells. This result presents two key implications. First, under the presumption that lower-income households tend to live in lower quality homes, the results highlight environmental justice concerns raised previously in the literature. Less wealthy selling households have less financial resources available to move and purchase a new housing bundle (Hird, 1994, pg 192; Chan, 2001), and so the lack of equity in their home and substitutable forms of wealth may deter them from re-optimizing in response to an environmental disamenity, at least more so relative to wealthier households. Second, this deterrence of transactions among lower quality homes suggests the potential for self-selection biases in conventional hedonic methods (at least in this specific application); a concern that has been raised previously in the literature (Simons et al., 1999; Knight, 2008).

Finally, a parallel hedonic property value study found little effect of the discovery of the typical leak, cleanup, and closure of the investigation on homes that were merely located in close proximity to these LUST sites (Guignet, 2013). However, that study did find that homes where the private well was tested for contamination, and hence the household was explicitly informed of the disamenity, did experience an 11% depreciation in the transaction price. And yet it is among these well-informed households that the current study reveals no effects on the probability of sale. Together these findings highlight the importance of information in a well-functioning property market. Among well-informed households, transactions continue and prices capitalize the disamenity. Among less-informed households, particularly those near sites with aggressive cleanup underway, and where people are left to form their own perceptions based on observed cleanup activities, we observe a significant slow-down in the local housing market.

A thorough discussion of the welfare implications is beyond the scope of this paper –but further investigation on this issue is warranted. Theoretically, it is ambiguous whether there are gains or losses from accelerating or slowing down home sales, and the issue becomes empirical (Guignet, 2014). However, we can add a few elements to the relatively informal and underdeveloped discussion on welfare changes due to changes in the optimal selling time. Simons et al. (1999), and Malone and Barrows (1990) have expressed concerns about limitations in the hedonic price methodology to capture disutility attributable to the delay in selling a home. Stated preference and focus groups studies on LUSTs have found that respondents were less likely to bid on hypothetical homes with degraded levels of environmental quality. Also, in the role of a seller, respondents were reluctant to sell and concerned with their ability to do so (Simons and Winson-Geideman, 2005; Alberini and Guignet, 2010). Results from this paper suggest that welfare effects may be at play even if the probability of sale returns to normal levels after the completion of cleanup; simply because the dynamically optimal time path for selling one's home is disrupted by the environmental disamenity. No studies to date have estimated the welfare effects associated with such disruptions (US EPA, 2011), and we believe that there is clearly a need for future research to fill this gap.

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APPENDIX

Table A1. Discrete-time Duration Models (Annual Probability of a Sale). Full set of coefficient estimates from models in Table 2.

VARIABLES	Full Sample Logit (1.A)	Full Sample Logit (1.B)
log(interior sqft)	-0.4885***	-0.4899***
	(0.033)	(0.033)
log(lot size)	-0.1340***	-0.1347***
	(0.013)	(0.013)
acres missing (dummy)	0.4835**	0.4740**
	(0.231)	(0.231)
number of full baths	0.1163***	0.1167***
	(0.012)	(0.012)
number of half baths	0.0689***	0.0686***
	(0.014)	(0.014)
basement (dummy)	-0.0336**	-0.0344**
	(0.015)	(0.015)
number of stories	0.2105***	0.2115***
	(0.020)	(0.020)
number of fireplaces	0.0425***	0.0420***
	(0.016)	(0.016)
fireplaces missing (dummy)	0.0457**	0.0448*
	(0.023)	(0.023)
porch size (sqft)	-0.0001***	-0.0001***
	(0.000)	(0.000)
porch missing (dummy)	0.0607**	0.0610**
	(0.025)	(0.025)
attached garage (dummy)	0.0655***	0.0652***
	(0.016)	(0.016)
low quality construction (dummy)	-0.6348***	-0.6354***
	(0.100)	(0.100)
good quality construction (dummy)	0.1756***	0.1768***
	(0.024)	(0.024)
high quality construction (dummy)	0.3214**	0.3189**
	(0.135)	(0.135)
construction quality missing (dummy)	0.5578**	0.5552**
	(0.240)	(0.240)
age of home	-0.0004	-0.0004
	(0.001)	(0.001)
age^2	0.0000	0.0000
	(0.000)	(0.000)

age missing (dummy)	-0.0869	-0.0902
	(0.241)	(0.241)
GW (dummy denoting in private groundwater well area)	-0.0851***	-0.0673
	(0.029)	(0.046)
distance to nearest public open space (meters)	0.0000	0.0000
	(0.000)	(0.000)
distance to nearest commercial zone (meters)	0.0000*	0.0000
	(0.000)	(0.000)
distance to nearest major road (meters)	-0.0000	-0.0000
	(0.000)	(0.000)
inverse distance to central business district	41.9697	38.8287
	(37.158)	(37.284)
Frederick County (dummy)	0.1187***	0.1217***
	(0.020)	(0.020)
Year 2001 (dummy)	-0.2519***	-0.2517***
	(0.049)	(0.049)
Year 2002 (dummy)	-0.3751***	-0.3747***
	(0.051)	(0.051)
Year 2003 (dummy)	-0.3648***	-0.3640***
	(0.057)	(0.057)
Year 2004 (dummy)	-0.0914	-0.0905
	(0.061)	(0.061)
Year 2005 (dummy)	-0.0079	-0.0075
	(0.066)	(0.066)
Year 2006 (dummy)	-0.0618	-0.0620
	(0.071)	(0.071)
Year 2007 (dummy)	-0.3126***	-0.3123***
	(0.076)	(0.076)
Period 2	0.2539***	0.2539***
	(0.043)	(0.043)
Period 3	0.4771***	0.4771***
	(0.045)	(0.045)
Period 4	0.4046***	0.4045***
	(0.050)	(0.050)
Period 5	0.2700***	0.2697***
	(0.057)	(0.057)
Period 6	0.1401**	0.1399**
	(0.062)	(0.062)
Period 7	0.0033	0.0031
	(0.069)	(0.069)
Period 8	-0.0197	-0.0197
	(0.077)	(0.077)
Censored	-0.0990***	-0.0984***
	(0.035)	(0.035)

# of USTs within 0-500 m	0.0041*	
	(0.002)	
LUST within 500 m	-0.0108	
	(0.026)	
× leak discovered	0.1105**	
	(0.044)	
× ongoing cleanup	-0.1076*	
	(0.063)	
× cleanup completion	0.0493	
	(0.038)	
# of USTs within 0-500 m × Public Water		0.0039
		(0.002)
LUST within 500 m × Public Water		-0.0164
		(0.027)
× leak discovered		0.1537***
		(0.047)
× ongoing cleanup		-0.0712
		(0.064)
× cleanup completion		0.0655
		(0.040)
# of USTs within 0-500 m × GW		0.0057
		(0.024)
LUST within 500 m × GW		-0.0016
		(0.086)
× leak discovered		-0.1186
		(0.128)
× ongoing cleanup		-0.7144**
		(0.305)
× cleanup completion		-0.0729
		(0.140)
Constant	-0.3030	-0.2937
	(0.223)	(0.223)
Observations	648,815	648,815

*** p<0.01, ** p<0.05, * p<0.1.
Std errors are in parentheses, clustered for same parcel for all years.

Table A2. Discrete-time Duration Models: Private Well Tests (Annual Probability of a Sale).

VARIABLES	Private Well Homes Logit (2.A)	Private Well Homes Logit (2.B)	Private Well Homes Logit (2.C)
# of USTs within 0-500 m	0.0069	0.0073	0.0068
	(0.024)	(0.024)	(0.024)
LUST within 500m	0.0322	0.0301	0.0323
	(0.088)	(0.088)	(0.088)
× leak discovered	-0.0480	-0.0450	-0.0493
	(0.133)	(0.134)	(0.134)
× ongoing cleanup	-0.6909**	-0.6918**	-0.6864**
	(0.307)	(0.306)	(0.306)
× cleanup completion	-0.0369	-0.0293	-0.0370
	(0.148)	(0.148)	(0.147)
Well Tested	-0.1264	-0.2217	-0.1733
	(0.201)	(0.272)	(0.224)
× Contaminated		0.2522	
		(0.390)	
× Above MCL			0.3075
			(0.449)
Period 2	0.1923	0.1924	0.1924
	(0.156)	(0.156)	(0.156)
Period 3	0.3832**	0.3834**	0.3833**
	(0.161)	(0.161)	(0.161)
Period 4	0.3136*	0.3134*	0.3135*
	(0.181)	(0.181)	(0.181)
Period 5	0.1452	0.1448	0.1451
	(0.212)	(0.212)	(0.212)
Period 6	0.2946	0.2940	0.2944
	(0.216)	(0.216)	(0.216)
Period 7	0.1902	0.1898	0.1899
	(0.244)	(0.244)	(0.244)
Period 8	-0.0190	-0.0191	-0.0195
	(0.294)	(0.293)	(0.293)
Censored	-0.1410	-0.1404	-0.1407
	(0.130)	(0.130)	(0.130)
Observations	76,616	76,616	76,616

*** p<0.01, ** p<0.05, * p<0.1. Std errors are in parentheses, clustered for same parcel over all years. Models are estimated on the subsample of single-family homes that rely on private groundwater wells. The dummy variables well tested, contaminated, and Above MCL denote that the private well was previously tested, contamination found, and contamination found to be above the maximum contaminant level (MCL) set forth by the U.S. Environmental Protection Agency. These results are robust when focus is drawn to only fairly recent tests and contamination results (i.e., within the last 1, 2, or 3 years).

Table A3. Discrete-time Duration Models: Treatment Heterogeneity by Home Quality and Water Source (Annual Probability of a Sale).

VARIABLES	Public Water Homes Logit (3.A)	Private Wells Homes Logit (3.B)
# of USTs within 0-500 m	0.0032	0.0040
	(0.003)	(0.025)
LUST within 500m	-0.0211	0.0411
	(0.027)	(0.087)
× leak discovered × lower	0.1499***	-0.0463
	(0.047)	(0.134)
× ongoing cleanup × lower	-0.0292	-0.8382**
	(0.066)	(0.356)
× cleanup completion × lower	0.0627	-0.0607
	(0.041)	(0.148)
× leak discovered × higher	0.0899	-0.3832
	(0.369)	(0.358)
× ongoing cleanup × higher	-0.4323*	-0.1388
	(0.224)	(0.583)
× cleanup completion × higher	0.1663	0.1267
	(0.148)	(0.529)
Period 2	0.2597***	0.1930
	(0.045)	(0.156)
Period 3	0.4857***	0.3835**
	(0.047)	(0.161)
Period 4	0.4126***	0.3141*
	(0.052)	(0.181)
Period 5	0.2795***	0.1454
	(0.059)	(0.212)
Period 6	0.1280**	0.2948
	(0.065)	(0.215)
Period 7	-0.0130	0.1901
	(0.072)	(0.244)
Period 8	-0.0187	-0.0187
	(0.080)	(0.294)
Censored	-0.0912**	-0.1408
	(0.036)	(0.130)
Observations	572,199	76,616

*** p<0.01, ** p<0.05, * p<0.1. Std errors are in parentheses, clustered for same parcel over all years.
Model 4.A is estimated on the subsample of single-family homes connected to the public water system, and model 4.B is estimated on the subsample of single-family homes that rely on private groundwater wells. Low end homes defined by home quality rated as "low" or "average" by tax assessors, and higher end homes are those rated "good" or "high."