# "Methods for Estimating Economic Damages from Environmental Contamination"

Dave Shideler, Oklahoma State University
dave.shideler@okstate.edu

Michael R. Dicks, Oklahoma State University
michael.dicks@okstate.edu

***Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, TX, February 5-8, 2011***

"Methods for Estimating Economic Damages from Environmental Contamination"

Dave Shideler and Michael R. Dicks, Oklahoma State University

## Abstract

While significant attention has been given to the decrease in property values associated with environmental contamination (i.e., stigma effects), little attention has been given to the stigma impacts on the local community as a whole. In addition, most estimates of stigma damages have been performed within a community, using distance from contamination or comparing contamination and non contamination areas in the community. In this article we determine stigma damages by analyzing property values in comparable communities and develop the rationale for estimating the community impact associated with environmental contamination that extends beyond the impact on individual property owners. These impacts were estimated for the environmental contamination from zinc smelting in the municipality of Blackwell, Oklahoma. The impacts were measured in terms of lost ad valorem tax revenue using hedonic pricing and average treatment effects.

**Introduction**

Blackwell, Oklahoma is located in Kay County, a nonmetropolitan county in north-central Oklahoma. It is approximately three miles east of Interstate 35 and 12 miles south of the Oklahoma-Kansas state line. Blackwell's population peaked in 1960 at 9,588; according to the 2005-2009 American Community Survey, its population is now about 7,200. Between 1916 and 1974, Blackwell was also home to Blackwell Zinc Company (BZC), a zinc smelting operation that processed cadmium and zinc to produce refined metal. This community suffered the contamination of heavy metals to the air, soils, structures and ground water in and around the community, as documented in the early 1990s when the Oklahoma Department of Environmental Quality did soil and groundwater testing. Even after remediation attempts by the parent company of Blackwell Zinc Company were completed in 2001, the water reservoir located beneath the town remained contaminated with cadmium. Town residents were told by Phelps Dodge (parent company of BZC) that deed restrictions may be necessary to inform future property owners about the contaminated groundwater. Local residents, fearing further declines in property values associated with the contamination, took action by suing Phelps Dodge for further clean-up and damages.

The literature available on estimating the economic damages from environmental contamination rely exclusively on the lost value of real estate appreciation. The methods for estimating the impacts of the environmental contamination include measures for both historic losses and future post clean-up losses. The lost value of real estate represents a lost income stream to the City of Blackwell from reduced ad valorem taxes resulting from diminished property values and reduced sales tax collections from a reduction in community population and business growth. For the purposes of this report, this lost stream of income from reduced taxes

will be referred to as “Stigma Damages” as an indication that the damages arise from the reduced desirability of the City of Blackwell boundary as a location for expanded housing and businesses.

**Background**

The literature on the analysis of the damages from environmental clean-up sites is large and found in numerous professional journals. Jackson (2001) provides a review of the literature on the effects of environmental contamination on Real Estate. He points out that the largest body of this work has focused on the appropriate methods for valuing contaminated property. A second body of work is that of empirical studies of the effects of contamination on real estate prices, both residential and commercial/industrial. These studies typically apply some type of hedonic analyses first developed by Griliches (1961) and later by Rosen (1974) who provided the theoretical underpinnings. The studies cover economic costs where contamination occurred to water, air and/or land and have included landfill sites, overhead power lines and noise pollution. These studies suggest three general scenarios to describe the response of real estate prices to an environmental spillover. In the most straightforward, the presence (or severity) of an environmental problem is associated simply with the constant presence (or severity) of a price discount on properties affected by the problem. In the second scenario, the presence (or severity) of an environmental problem is associated with a price discount on properties affected by the problem, but the magnitude of the discount evolves in the same way that marginal prices on other hedonic attributes evolve (Case et.al.,2006). Case suggests a third and unique scenario to describe the response to real estate prices by including a determination of whether transaction prices capture a sorting process that occurs over time as those who are willing to pay less to live in a contaminated environment migrate into the area while those willing to pay more to live

outside the contamination area migrate away from the area. This exchange of families is itself a cost that is reflected in slower economic growth and increased location stigma.

Aydin and Smith (2008) build on the argument of Case et.al., describing the price recovery of real estate in the "remediated" neighborhoods, but noting that the increased negative demographics (low income, poor schools, lower housing maintenance, etc) that occurred following the public announcement of the environmental contamination in proximity to the area is slow to recover.

Patchin (1988) provided the first framework for estimating the lost value of contaminated real estate using a repeat sales model to measure changes in price over time in the market. Patchin (1991) noted that property values can decline from the perception that contamination exists and delineated the factors he believed contributed to this perception that "stigma" exists. These factors include 1) the fear of hidden abatement costs, 2) the resistance of the market to conclude that abatement is complete, and 3) the "trouble" associated with continued efforts at actual abatement or removing the market resistance (perception of incomplete abatement). Patchin noted that the decline in market value of a contaminated property that is greater than the cost to abate the contamination is the stigma effect. Jackson (1997) listed a number of factors that were important in determining stigma damages including: (1) cost and timing of remediation; (2) indemnifications; (3) certainty about the nature and extent of contamination; (4) potential business interruption costs; (5) an available abatement plan; (6) strength of existing regulations; and (7) the probability of third-party lawsuits. Jackson uses a discounted cash flow model (DCF) to measure the effects of the contamination of property values. He used remediation costs deducted from income during the period of contamination (prior to complete abatement), and an

increase in the property's overall yield rate to account for the additional risk or stigma associated with the contamination. He found that risk premiums of 500 basis points were not uncommon.

Following on Patchin's effort, Rinaldi (1991) suggested that the valuation of contaminated properties should be accomplished by first estimating the value of the property as if it were uncontaminated, and then analyzing the loss in value as a result of the contamination. A recent analysis by Case et.al. (2006) used a hybrid hedonic and repeat-sales model to estimate the impact of externalities on real estate prices. The hedonic model is superior to the repeat-sales model when repeat sales data is limited.

Greenberg and Hughes (1992) provide the only known analysis of the impacts of environmental contamination on real estate values using comparative analysis of communities with and without proximity to superfund sites. They found that sales prices tend to increase less in superfund communities than in similar non-superfund communities. The authors found this method valuable when small communities are totally engulfed by the contaminated area and there is no means to measure the difference in value of real estate over time between areas in the community both affected and not affected by the superfund site.

Finally, Gayer et.al. measured the value that residents place on avoidance of hazardous wastes sites prior to and after the issuance by the Environmental Protection Agency's "Remedial Investigation". Their study indicates that hazardous waste site residents' overestimate the risk from living near the site. This demonstrated tendency to overestimate the low-probability health risks underscores the importance of stigma damages.

**Methods**

This analysis takes the estimates of stigma damages on the contaminated community beyond the effect on real estate values and extends the damages to the municipal authority.

Estimated stigma damages are the losses suffered by the City of Blackwell as a result of lost tax revenue associated with the reduced number and value of homes and businesses, both in the past and in the future. We use 1980 as the base period for estimating changes in the number and value of business and homes as this was the date of the first community wide experience with the contamination and the potential health effects of that contamination. The estimates of the reduced value of real estate in Blackwell, Oklahoma were generated using two methods. First, hedonic pricing models were used to identify the relative differential of real estate prices between Blackwell and 15 similar communities in Oklahoma. While this methodology provides insight into the magnitude of the price differential between communities, the results cannot be interpreted as causal. So a second methodology, called average treatment effects, was used to establish the causality that being in Blackwell is the cause of the price differential and not other observable factors. The hedonic model is then use to determine the lost value of real estate in Blackwell as a result of the contamination. These values include the lost value of existing real estate as well as the lost value of real estate from homes not built. Using the millage rate for the city we determine the lost revenue to the city of Blackwell both in the past and into perpetuity. Following a description of the data used, the discussion will be divided into two parts to emphasize the results of each methodology.

Real estate data were collected for 16 communities in Oklahoma using PVPlus. PVPlus is a proprietary database of property assessment data available at www.pvplus.com. Sales data from 2004 to 2009 were collected for all residential homes sold during this period. Characteristics of the properties included, home square footage, total number of rooms, bedrooms, bathrooms, age, assessor-determined condition, existence of garage, porch or basement, and presence of HVAC. Dummy variables for each community were included to

control for community differences; Blackwell was excluded so that all the parameter values of the community variables could be interpreted as marginal effects relative to Blackwell. The comparison communities were chosen because they were similar in population in 1980, distance from a major metropolitan area and interstate highways. The 15 comparison communities are (in alphabetical order): Anadarko, Clinton, Cushing, Guthrie, Henryetta, Hugo, Pauls Valley, Perry, Poteau, Pryor, Sallisaw, Sayre, Seminole, Sulphur, and Vinita. This information was used in a hedonic model to determine if the price of housing in Blackwell was significantly different from that in the other 15 communities. Some observations had to be excluded due to missing data, they were deemed to be an outlier (e.g., the sale price fell outside of two standard deviations of the mean), or they represented a duplicate entry. Additional adjustments to the data set involved multiple sales of a single property within a given year. For sales dated within one month of each other, the entry with the larger value was dropped from the dataset. Also, if a property sold multiple times in a year for the same price, the prices were adjusted to be $0.01 different from one another. Properties with sales prices equal to zero were deleted; due to this step, all observations from Cushing and Guthrie were dropped from the dataset.

The results of the hedonic pricing model are found in Table 1. When interpreting these results, one must recognize two key facts. First, the parameter estimates represent the additional contribution to the (natural logarithm of) price in Blackwell in 2009. Thus, the positive and significant parameter estimates associated with the location variables suggest the additional value of a home ***not*** located in Blackwell. A three bedroom, two bathroom, 1,500 square foot, 20 year old house (with a total of nine rooms), with garage and central air, was estimated to have a price of $42,788 in Blackwell in 2009. The same house would have a price of $56,665 in Hugo and $91,102 in Pauls Valley.

To further support these findings, average treatment effects were calculated to demonstrate causality. Average treatment effect is a methodology that compares outcomes between a control group and a treatment group. For this research, the treatment group consisted of properties located in Blackwell. Average treatment effects uses ordinary least squares to estimate coefficients on the difference in values between matched observations between the control and treatment groups; by differencing the observed values of matched observations, only those characteristics for which significant differences exist remain in the regression to explain the observed difference in prices. Theoretically, the only difference between the matched observations is the treatment, or in this case, the location of the property. The procedure matched property records from both groups using a propensity score, which is an index based upon property characteristics, and a kernel matching algorithm that matches each member of the treatment group to an average of control members in a corresponding block (or subset) of observations. This two-stage matching procedure minimizes the error that can be introduced into the analysis due to matching observations using multiple characteristics. Tests were used to ensure that the statistical properties of the matched treatment and control groups across subsets were similar prior to computing the average treatment effect. Due to the complexity involved in matching over 10,000 observations in the pooled dataset, this analysis was performed on each year of data in the sample. The results are presented in Table 2.

The results of the average treatment effects provide strong evidence that, in all but one year, the difference in housing prices between Blackwell and the other communities was due to the property's location. A property lost between 25% of its value (measured as price) in 2004 and 61% of its value in 2008 by being in Blackwell. Only in 2007 were prices in Blackwell statistically comparable to those in other communities.

The purpose of this paper, however, is not simply to estimate the property value loss due to the contamination in Blackwell, but to estimate the impact such value loss had on public services funded through ad valorem taxes. The hedonics model is used to estimate the lost value of existing residential real estate as a result of the stigma associated with the Zinc smelter contamination. The total impact of the stigma can be estimated as:

$$S_t = PT_t + ST_t \text{ , where} \quad (1)$$

$$PT_t = LRV_t \times AV_t \times MR_t \quad \text{and} \quad ST_t = LVC_t \times STR_t \quad (2)$$

Where

$S_t$ = Value of Stigma in time t,
$PT_t$ = Property tax in time t,
$ST_t$ = Sales tax in time t,
$LRV_t$ = Lost real estate value in time t,
$AV_t$ = Appraised real estate value in time t,
$MR_t$ = Millage Rate in time t,
$LVC_t$ = Lost construction value in time t,
$STR_t$ = Sales Tax Rate in time t.

And both LRV and LVC include the lost value on existing homes as well as the lost value of homes not built as a result of the stigma. Table 3 below summarizes the past and future lost property tax associated with the reduced value of existing residential real estate as a result of the stigma damages. For past damages, the lost value of existing homes was estimated as the difference between the hedonic price prediction in Blackwell and the average across all other communities, using the features of an average home described above; this difference is $28,150. Future lost values were estimated as the difference between the predicted price in Blackwell and next lowest predicted price, which was in Hugo, or $14,517.

To estimate the lost value of homes not built a simple model of expected number of homes was used as;

Housing starts (%built 1980-2007) =f(popcity, popcounty) where;

popcity = the % change in the population of the 16 communities from 1980 – 2007
popcounty = the % change in the county population of the 16 communities, 1980 – 2007

This model predicted that housing starts should have increased by 13.3%, however actual starts were only 7.4%. The total housing units in Blackwell are estimated at 3,527 in 2009 and thus an estimated 209 houses were not built as a result of the stigma. The cost per square foot of building these houses was estimated as the current (2009) value of construction ($83 per square foot) deflated to each specific year.

For the years from 1980 to 2009, the actual values for millage rate and sales tax rate are known. For years beyond 2009, the discounted value of Stigma is measured using the 2009 value and a discount rate of four percent. Table 4 summarizes the lost real estate values and taxes associated with the homes not built as a result of the stigma.

The total impact, past and future associated with the stigma attached to the environmental contamination from the zinc smelter is estimated at approximately $12.7 million. This represents the lost revenues to the city of Blackwell from the sales and property taxes that would have occurred in the absence of the environmental contamination. While these represent the direct impacts of the contamination on the city tax collections, additional damages may occur as a result of not spending this $12.7 million on city infrastructure and services. That is, because the city has not provided the additional services or facilities associated with the $12.7 million, the "livability" of the city is and will continue to be reduced.

**Discussion and Conclusions**

The literature is clear that a "stigma" damage occurs when problem effects or is perceived to effect real property. Following the work of Rinaldi (1991) this study uses a hedonic analysis of similar communities to determine the value of contaminated properties as if it were uncontaminated, and then analyzing the loss in value as a result of the contamination.

This comparison was accomplished using sales data on residential properties in 16 similar communities. While the lost value of the affected residential properties in Blackwell was large, this loss is suffered by the homeowners. However, the city has also lost a stream of revenue in the form of property and sales taxes as a result of the lost value of existing residential real estate and the lost value of residential properties not constructed as a result of the stigma associated with the environmental contamination.

Because the city is an entity not unlike any other business, this lost stream of income has impeded the city's ability to service the citizens with services and facilities and is thus a measure of the stigma's impact to the city. We make no claim on the legality of this stigma damage but provide the framework for determining the extent to which the city, as an entity, suffers independent of the negative effect on wealth of the local residential property owners. What this means in necessary adjustments to the stigma effects on these property owners is unclear and opens a new area of work to determine the total stigma damages and the appropriate allocation of the portions of those damages to residential, business and public property owners.

**References**

Aydin, R and B.A. Smith. “Evidence of the Dual Nature of Property Value Recovery following Environmental Remediation.” *Real Estate Economics* 36:4 (2008):777-812

Case, Bradford, Peter F. Clolwell, Chris Leishman and Craig Watkins. “The Impact of Environmental Contamination on Condo Prices: A Hybrid Repeat-Sale/Hedonic Approach.” *Real Estate Economics* 34:1 (2006): 77-107.

Griliches, Z. “Hedonic Price Indexes for Automobiles:An Econometric Analysis of Quality Change.” (1961)New York: Columbia University Press

Greenberg, M. and J. Hughes. “The Impact of Hazardous Waste Superfund Sites on the Value of Houses Sold in New Jersey.” *Annals of Regional Science* 26: 2(1992): 147 -153.

Gayer, Ted, James T. Hamilton and W. Kip Viscusi. “Private Values of Risk Tradeoffs at Superfund Sites: Housing markets Evidence on Learning About Risk.” *The Review of Economics and Statistics* 83:3 (2000):439-451.

Jackson, Thomas O., “The Effects of Environmental Contamination on Real Estate: A Literature Review.” *Journal of Real Estate Literature* 9:2 (2001):93-116

Jackson, Thomas O., “Investing in Contaminated Real Estate”, Real Estate Review: 1997, 26:5, 38-43

Patchin, P.J., “Valuation of Contaminated Properties: Its effect on Proerty Values and Cities”, *The Appraisal Journal,* 1988, 56:1, 7-16.

Patchin, P.J. “Contaminated Properties: Stigma Revisted”, *The Appraisal Journal,* 1991, 59:2, 167-172.

Rinaldi, A.J. “Contaminated Properties: Valuation Solutions”, *The Appraisal Journal*, 1991, 59:3, 377-381.

Rosen, S. “Hedonic Prices and Implicit Markets.” *Journal of Political Economy* 82 (1974):34-55.

**Table 1. Hedonic Model Results**

| Variable | Parameter Estimate | T-Statistic |
|---|---|---|
| Constant | 4.1353 | 19.93*** |
| Number of Bedrooms | 0.0125 | 1.20 |
| Number of Bathrooms | 0.1574 | 8.38*** |
| Central Air Conditioning (1= yes, 0= no) | 0.5703 | 28.48*** |
| Garage Available (1= yes, 0= no) | 0.3700 | 20.20*** |
| Basement Available (1= yes, 0= no) | 0.0994 | 1.73* |
| Square Footage of Home (transformed by the natural logarithm) | 0.6975 | 22.32*** |
| Age of Home (transformed by the natural logarithm) | 0.0400 | 5.03*** |
| Sold in 2004 (1=yes, 0= no) | -0.1567 | -5.19*** |
| Sold in 2005 (1=yes, 0= no) | -0.0955 | -3.15*** |
| Sold in 2006 (1=yes, 0= no) | 0.0267 | 0.89 |
| Sold in 2007 (1=yes, 0= no) | 0.0945 | 3.18*** |
| Sold in 2008 (1=yes, 0= no) | 0.0729 | 2.36** |
| Home Located in Seminole (1= yes, 0= no) | 0.4018 | 10.40*** |
| Home Located in Anadarko (1= yes, 0= no) | 0.4080 | 7.32*** |
| Home Located in Clinton (1= yes, 0= no) | 0.3828 | 10.58*** |
| Home Located in Perry (1= yes, 0= no) | 0.4306 | 10.86*** |
| Home Located in Sulphur (1= yes, 0= no) | 0.6448 | 13.65*** |
| Home Located in Hugo (1= yes, 0= no) | 0.2960 | 6.16*** |
| Home Located in Sayre (1= yes, 0= no) | 0.4080 | 7.59*** |
| Home Located in Henryetta (1= yes, 0= no) | 0.3009 | 7.34*** |
| Home Located in Pauls Valley (1= yes, 0= no) | 0.7708 | 19.47*** |
| Home Located in Sallisaw (1= yes, 0= no) | 0.6396 | 15.25*** |
| Home Located in Vinita (1= yes, 0= no) | 0.4994 | 12.10*** |
| Home Located in Poteau (1= yes, 0= no) | 0.5200 | 14.15*** |
| Home Located in Pryor (1= yes, 0= no) | 0.7828 | 21.64*** |
| | | |
| Sample Size | 10,280 | |
| F-Statistic | 273.32*** | |
| $R^2$ | 0.400 | |
| Adjusted $R^2$ | 0.398 | |
| | | |

*** Statistical significance at the 1% level

** Statistical significance at the 5% level

* Statistical significance at the 10% level

**Table 2. Average Treatment Effect Results**

| Year | Treatment Effect | T-statistic* |
|---|---|---|
| 2004 | -0.248 | -3.704*** |
| 2005 | -0.408 | -6.391*** |
| 2006 | -0.575 | -6.591*** |
| 2007 | -0.082 | -0.723 |
| 2008 | -0.611 | -7.505*** |
| 2009 | -0.395 | -5.238*** |

* Standard errors used to calculate the T-statistic determined by bootstrapping using 100 repetitions.
*** Statistical significance at the 1% level.

**Table 3. Lost Tax Revenue From Reduced Property Values**

| | Accumulative Lost Housing Value | Total Lost Appraised Value | Total Lost Tax |
|---|---|---|---|
| Past (1980-2009) | $1,985,697,434 | $218,426,718 | $1,972,175 |
| Future (2010 & forward) | $1,254,680,564 | $138,014,862 | $1,246,136 |
| Total | | | $3,218,311 |

**Table 4. Lost Tax Revenue From Foregone Residential Construction**

| | Accumulative Lost Housing Value | Total Lost Property Tax | Total Lost Sales Tax on Construction | Total |
|---|---|---|---|---|
| Past | $244,571,040 | $242,906 | $2,384,568 | $2,627,473 |
| Future | $638,211,992 | $633,866 | $6,222,567 | $6,856,433 |
| | | | | $9,483,906 |