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STIGMATIZED ASSET VALUE: IS IT TEMPORARY OR PERMANENT?

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Abstract: Stigma is a negative attribute of real estate acquired by the discovery of contamination and reflected in its value (Elliot-Jones, 1996). Using a theoretical model with external economies and adjustment costs, we show that both temporary stigma and permanent stigma are possible equilibrium outcomes after the discovery and cleanup of a hazardous waste site. The existence and duration of stigma are examined using hedonic price techniques with data from housing sales prices in Dallas County, Texas. The empirical evidence shows that stigma exists after cleanup only for properties in very close proximity to the hazardous waste site.

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I. Introduction

The public has become increasingly aware of environmental risks since the 1970's. This awareness is reflected in the negative impact of environmental contamination on property values. Stigma is a negative attribute of real estate acquired by the discovery of contamination and reflected in price (Elliot-Jones, 1996). The two possible causes of stigma are uncertainty and path dependence. If the less obvious cause, path dependence, is present, then reversing an event (such as cleaning up a hazardous waste site) will not result in the same outcome that would occur had the event never occurred. Another term that could be used in place of path dependence is hysteresis, *viz.*, history matters. The uncertainty that causes stigma is over whether the property is still a health risk after cleanup and potential future cleanup liabilities. Some analysts have argued that uncertainty is a cause of stigma (Mundy, 1992), but no one has considered path dependence.

Once environmental contamination becomes associated with a particular neighborhood, its property values may be stigmatized. Consider Love Canal: even if a potential homebuyer believes that this area has been cleaned up, he or she will probably demand a discount for a Love Canal address. The resale value will most likely be lower than a comparable property without a history of contamination, if there is a market for the residential property at all. He or she may also consider that the type of person who would buy a house with a Love Canal address may not be an ideal neighbor. This reluctance to buy can be reflected in lower residential property values and may be based on perceived risk that has no scientific foundation.

A neighborhood may be distinguished as undesirable if it is identified as contaminated. It becomes an unfashionable address. Real estate has an intangible component, which is the public's perception of the location. This is similar to the intangible asset of goodwill on a corporation's balance sheet. When the public perceives a neighborhood to no longer be fashionable, the value of the intangible component of property values falls. The past presence of the hazardous waste site can affect the time path of the composition of residents in the neighborhood and other attributes which determine neighborhood quality and property values. By making the neighborhood less desirable, the hazardous waste site decreases the value of the neighborhood's property, making it more affordable to lower-income families and less attractive to higher-income families. Over time, higher-income residents will relocate, and, as a result, the by-products of high-income residents, such as social status, good schools, low crime rates, quick police response, and well-maintained, owner-occupied homes may disappear. Therefore, temporary environmental problems may permanently change the character of a neighborhood creating stigma.[1] In a worst case scenario, outside business may "redline" the area causing neighborhood businesses to relocate. In this scenario, it is unlikely property values will rebound.

A likely scenario is that property values will rebound to some extent after cleanup, but they will not be as high as they would have been if the hazardous waste site had never existed. This is not the only possible scenario. It may also be the case that property values completely recover after cleanup. Property values could also actually fall after cleanup. In this perverse scenario, if there is negative publicity surrounding the cleanup, it is possible that property values could well decline.

Previous studies have attempted to measure benefits from the cleanup of hazardous waste by showing that residential property values decline as the distance to a hazardous waste site decreases (for example, Ketkar, 1992; Thayer *et al.*, 1992). Extending this argument, if the hazardous waste site is removed, then the discount for being in a location that is close to a former hazardous waste site should be recouped. After environmental contamination is remediated, *ceteris paribus*, one would expect residential property values to regain their lost values. According to this argument, the benefits of cleanup are then the difference between what property values were without the hazardous waste site and what property values are with the hazardous waste site. As discussed earlier, if there is path dependence, then this reasoning is faulty. Consequently, if stigma effects from a site exist, then past studies that have made this value recoupment argument may have overestimated the benefits of cleanup of hazardous waste sites.

Another possible cause of stigma is uncertainty. There are two major sources of uncertainty: (1) whether the property is still a health risk even after the property has been remediated and (2) what future potential liabilities exist and who is responsible for them. Using an expected utility approach, it can be shown that the uncertainty surrounding hazardous waste sites can result in lower property values (Boyd *et al.*, 1996). More generally, a monetary value can be placed on irreversible events such as a permanent change in health status and loss of life, based on the choices an individual makes about income, consumption and risk. A potential buyer must be compensated for the expected value of future damage to his health and an amount equal to a certainty equivalent to compensate for the risk associated with the contaminated site.

Uncertainty can also make it difficult for prospective buyers to obtain financing. Lenders have become increasingly aware of the risks of mortgaging contaminated properties. Lenders' willingness to provide financing on contaminated properties fell from the late 1960's to a low point in the early 1980's where it stayed until the early 1990's, when it started to increase again. During the low willingness-to-finance period, the vast majority of lenders would not consider providing financing until the property has been cleaned up and tests within required limits. The net result of the loss of mortgagability is often that the property is held off the market.[2] However, a recent increase in the understanding of the management of the risk surrounding contaminated properties has lead to a greater willingness to provide financing for these properties.

A potential additional source of uncertainty emerges over future property values and attributes caused by self-fulfilling prophecies. Prospective buyers and sellers can also have expectations over which equilibrium will eventually win out. If after cleanup, a property owner believes her neighborhood is clean, but she thinks that her neighbors do not believe the neighborhood is clean, then she may expect relative neighborhood property values to decline. These expectations of his neighbors' expectations may lead her to believe that the higher-income neighbors will relocate. The classic example of self-fulfilling prophecies is the "Big Push" story told by Rosenstein-Rodan (1943). In this scenario, the willingness of firms to invest depends on their expectation that other firms will invest, so that the objective of development policy is to create convergent expectations around high investment. Models with multiple equilibria driven by expectations have also appeared in the industrial organization and macroeconomics literatures. In industrial organization literature, expectation-driven multiple equilibria appear in models with network externalities, such as Farrell and Saloner's (1986) model of technology adoption. In the macroeconomics literature, these equilibria result from models of economies with search, such as Howitt and McAfee (1988).

In this paper, we use a theoretical model with external economies and adjustment costs to show that both temporary stigma and permanent stigma are possible equilibrium outcomes after the discovery and cleanup of a hazardous waste site. The former is driven by risk and uncertainty, while the latter is the result of path dependence. The existence and duration of stigma are then tested for by estimating a hedonic price model with data from housing sales prices in Dallas County, Texas. The RSR lead smelter in West Dallas, which operated from 1934 to 1984, caused soil contamination from air emissions and slag material. The pooled data set used in this analysis covers the period 1979 to 1995 and includes over 200,000 observations. Finally, the separable causal effect of media coverage is analyzed over time.

II. Previous Empirical Studies

The current body of literature on the empirical effects of locally undesirable land uses does not address whether the diminution of property values caused by these land uses is temporary or permanent or whether path dependence effects exist. Although there have been many previous studies which attempt to measure the effect of environmental contamination and cleanup on property values, they focus on a short-run phenomenon. Most importantly, existing studies have not analyzed post-cleanup property values. Typically, impacts of contamination on property values are examined with a cross-sectional data set at a single point in time.[3] By not including post-cleanup property values, these studies cannot structure the event analysis correctly to analyze the effects of cleanup.

Many authors have used property value data to value environmental attributes and, more specifically, study the impact of hazardous waste sites. Researchers, such as Ketkar (1992), Kiel (1995), Kiel and McClain (1995), Kohlhase (1991), Smith and Desvousges (1986), and Thayer *et al.* (1992) have consistently found that proximity to hazardous waste sites and other locally undesirable land uses (LULUs) has a negative impact on property values.[4]

Contingent valuation is an alternative approach to property value studies for estimating benefits from the cleanup of hazardous waste sites. For example, Burness *et al.* (1983) and Smith and Desvousges (1986) have used contingent valuation to estimate willingness to pay to reduce the risk associated with a hazardous waste site. However, as

Thayer *et al.* (1992) point out, "The efforts have had little success because respondents apparently have significant difficulties assessing changes in low probability events."[5]

In contrast to previous empirical studies, this analysis examines impact of environmental contamination on residential property values by analyzing data from before identification of the hazardous waste site, and before, during, and after cleanup has been completed. Consequently, it is possible to consider the longer-run recovery prospects.

III. Multiple Equilibria Model

Permanent stigma is not the only possible outcome after environmental contamination. In reality, sometimes property values recover after cleanup, and sometimes they do not. Also, the recovery may be delayed, resulting in a temporary stigma. Accordingly, the theoretical model designed for our analysis has multiple equilibria. We show that environmental contamination can either lead to a permanent stigma on property values in formerly contaminated neighborhoods or a recovery.[6] In a stigma equilibrium, after it is revealed that their neighborhood is contaminated, the high-income residents move out and are replaced by low-income residents. After the relocations take place, it is announced that the neighborhood has been completely cleaned up. Upon hearing this news, the higher-income people do not reverse their decisions, and the price of houses in the formerly contaminated neighborhood do not rebound. In a recovery equilibrium, the high-income residents do not move out in the first place, and prices eventually return to normal.

Following Krugman (1991), we present a dynamic model in which both history and expectations can determine the choice of equilibrium. Previous discussion about stigma has focused only on uncertainty of health risk and liability as a cause (Mundy, 1992). On the other hand, externality models have been developed in the "tipping" or residential succession literature that emphasize the role of income levels or racial composition in explaining neighborhood turnover (Miyao, 1978; Coulson and Bond, 1990). If low-income residents enter a high-income neighborhood, then the composition of the neighborhood may tip from high income to low income. Consequently, the model advanced in this analysis makes a contribution to the tipping literature by showing that with external economies and adjustment costs, both path dependence and expectations can play a role in determining the neighborhood equilibrium.

In the model specification, there are two types of individuals: high-income and low-income. Both types have the same preferences; the only difference is income. Both types would like to live in a neighborhood with a high proportion of high-income people. Utility is generated by:

$$u(t) \equiv u\left(\eta(N(t)), q(N(t)), x(t)\right) \tag{1}$$

Where

$N(t) = \{N_1(t), N_2(t)\}$ is the individual's choice of neighborhood.

$q(N(t))$ is perceived environmental quality of $N(t)$.

$\eta(N(t))$ is the proportion of high-income types living in the neighborhood N.

$x(t)$ is all other goods.

$y_b(t)$ is endowment income ($b = l, h$; for low and high, respectively)

Individuals' income goes toward rent on a house and all other goods. Assuming that there is no borrowing or lending, an individual's budget constraint is then:

$$p\left(\eta(N(t)), q(N(t))\right) + (x(t)) = y_b(t) \tag{2}$$

Where $p\left(\eta(N(t)), q(N(t))\right)$ is the hedonic price, a market rental price of housing.[7] We assume it takes the following linear form:

$$p \equiv \alpha + \beta_1 \eta(N(t)) + \beta_2 q(N(t)). \tag{3}$$

We also specify utility as linear without loss of generality

(4) $$u \equiv q\big(N(t)\big) + \gamma\eta\big(N(t)\big) + \xi x$$

The parameter γ is then the marginal utility of the proportion of high-income people living in one's neighborhood, and ξ is the marginal utility of all other goods. Substituting the budget constraint into Equation 4, we obtain

(5) $$u \equiv \xi\big(y_b - \alpha\big) + \big(1 - \xi\beta_2\big)q\big(N(t)\big) + \big(\gamma - \xi\beta_1\big)\eta\big(N(t)\big)$$

The interpretation of Equation 5 is that utility can be expressed as a linear combination of the environmental quality of one's neighborhood, the proportion of high-income residents in one's neighborhood, and the consumption of all other goods.

In order for path dependence to exist, there must be some cost of adjustment. Consequently, we incorporate positive relocation costs in the model. Moving costs are based on the rate at which residents relocate between neighborhoods. Specifically, the cost of a move is specified as $\theta\dot{\eta}\big(N(t)\big)$. This type of adjustment cost has been referred to as a congestion cost, following Krugman (1991). The most compelling argument in support of this assumption is that congestion increases search costs. An additional argument in support of this assumption is that there are a limited amount of resources that are dedicated to moving services. As more and more people want to move at the same time, the price of moving services gets bid up. The present value benefit from moving to N_1 is

(6) $$m(t) = \int_t^T e^{-t(s-t)}\Big[\big(1 - \xi\beta_2\big)\Big(q\big(N_1(t)\big) - q\big(N_2(t)\big)\Big) + \big(\gamma - \xi\beta_1\big)\Big(\eta\big(N_1(t)\big) - \eta\big(N_2(t)\big)\Big)\Big]ds$$

The equilibrium condition is then that the marginal benefit is equal to the marginal cost of moving.

(7) $$\theta\dot{\eta}\big(N(t)\big) = m(t)$$

Using Leibnitz rule, we obtain

(8) $$\overset{\circ}{m} = rm - \left[\left(1-\xi\beta_2\right)\left(q\left(N_1(t)\right)-q\left(N_2(t)\right)\right)+\left(\gamma-\xi\beta_1\right)\left(2\eta\left(N_1(t)\right)-1\right)\right].$$

Where r is an interest rate. Equations (7) and (8) can be expressed as the following system of differential equations:

(9) $$\begin{bmatrix} \dot{m} \\ \dot{\eta} \end{bmatrix} = \begin{bmatrix} r & -2\gamma+2\xi\beta_1 \\ 1/\theta & 0 \end{bmatrix}\begin{bmatrix} m \\ \eta \end{bmatrix} + \begin{bmatrix} \left(1-\xi\beta_2\right)\left(q\left(N_1\right)-q\left(N_2\right)\right)-\gamma+\xi\beta_2 \\ 0 \end{bmatrix}.$$

Since (9) is a linear system, we can obtain the following analytical solution:

(10)

$$\begin{bmatrix} m(t) \\ \eta\left(N_1(t)\right) \end{bmatrix} =$$

$$\begin{bmatrix} \theta & \theta \\ \frac{2}{r+\sqrt{r^2-\frac{8\gamma}{\theta}+\frac{8\xi\beta_1}{\theta}}} & \frac{2}{r-\sqrt{r^2-\frac{8\gamma}{\theta}+\frac{8\xi\beta_1}{\theta}}} \end{bmatrix}\begin{bmatrix} \frac{2}{r+\sqrt{r^2-\frac{8\gamma}{\theta}+\frac{8\xi\beta_1}{\theta}}}\left[\left(1-\xi\beta_2\right)\left(q\left(N_1\right)-q\left(N_2\right)\right)-\gamma+\xi\beta_2\right]+c_1\exp\left[-t\left(\frac{r+\sqrt{r^2-\frac{8\gamma}{\theta}+\frac{8\xi\beta_1}{\theta}}}{2}\right)\right] \\ c_2\exp\left[-t\left(\frac{r-\sqrt{r^2-\frac{8\gamma}{\theta}+\frac{8\xi\beta_1}{\theta}}}{2}\right)\right] \end{bmatrix}$$

Where c_1 and c_2 are determined by initial conditions. The possible phase planes are shown in Figures 1 and 2.

There are three steady states, two of which are stable. The steady states with the proportion of high-income residents equal to zero and one are stable. Depending on the choice of parameters, there are two possible trajectories: one in which the proportion of high-income residents changes monotonically (see Figure 1) and another in which the proportion of high-income residents both increases and decreases due to a spiral trajectory (see Figure 2.) In the monotonic case, only history matters; while in the second case, both history and expectations determine the evolution of the neighborhood. In the monotonic case, the dynamic behavior of the model is straightforward. If the initial proportion of high-income residents is above η^* (see Figure 1), then the proportion of high-income residents will go to one. Conversely, if the initial proportion of high-income residents is below η^*, then the proportion of high-income residents will go to zero. In the spiral trajectory case, there is a range of values of the proportion of high-income residents, from η_1 to η_2 (see Figure 2), from which either equilibrium can be attained. Within that range, the equilibrium, which is reached is based on expectations. Given an initial proportion of high-income residents that is between η_1 to η_2, there exists at least one set of self-fulfilling expectations that lead to either equilibrium.

For expectations to matter, the system of differential equations in (9) must have complex roots or $r^2 - \frac{8\gamma}{\theta} + \frac{8\xi\beta_1}{\theta} < 0$. As the interest rate, r, increases, then people more heavily discount the future, and they become less willing to make a decision that trades current consumption for greater future consumption. Consequently, expectations will not play a role. If θ is large, then the cost of moving will be higher, which may cause expectations about the future to be relatively less important. If the marginal utility of the proportion of high income residents in one's neighborhood, γ, is small, then the externality effect is small, and a high-income person will care little about who his neighbors are, which may mask the role of expectations. Finally, if the marginal utility of all other goods, ξ, or the hedonic price of a location in a high-income neighborhood, β_1, is large, it will make the externality effect less important and may diminish the impact of expectations.

The model demonstrates that it is possible to arrive at either a permanent stigma equilibrium or a recovery equilibrium. If the recovery equilibrium is the one that eventually emerges, there will only be a temporary stigma on property values. Until the recovery equilibrium is reached, property values will be lower than they otherwise would have been. In our empirical analysis, we will determine which of these equilibria emerged for the residential properties in close proximity to the RSR hazardous waste site in Dallas, Texas.

IV. Statistical Model

The price of housing and land reflects consumers' valuations of all the attributes that are associated with housing, including environmental quality. The level of environmental quality can be considered to be a qualitative characteristic of a differentiated good market. Consumers can choose the level of environmental quality through their choice of a house. Housing prices may include premiums for locations in areas with high environmental quality. If so, the price differentials may be viewed as implicit prices for different levels of environmental quality.

Following the standard hedonic price model, the price of housing, *P*, in Dallas County, Texas, is assumed to be described by a hedonic price function, $P = P(x)$, where x is a vector of structural, neighborhood and environmental attributes. The hedonic price of an additional unit of a particular attribute is determined as the partial derivative of the hedonic price function with respect to that particular attribute. Each consumer chooses an optimal bundle of housing attributes and all other goods in order to maximize utility subject to a budget constraint. The chosen bundle will place the consumer so that his indifference curve is tangent to the price gradient, P_x. The marginal willingness to pay for a change in a housing attribute is then equal to the coefficient of the attribute (Rosen, 1974).

Our study follows the previously sited literature and considered only linear and semi-log (natural logarithm of the dependent variable) functional forms. A linear specification has the obvious interpretation that a unit increase in an attribute causes the price to rise by an amount equal to the coefficient; while with a semi-log specification, the coefficients can be interpreted as a percent of the average house price. Given the presence of independent dummy variables, the following Box-Cox transformation of the dependent variable was used to choose between the linear or natural logarithmic forms for the dependent variable.

(11)
$$p(\lambda) = \begin{cases} \dfrac{P^{\lambda} - 1}{\lambda}, \lambda \neq 0 \\ \ln \lambda, \quad \lambda = 0 \end{cases}$$

Using Box-Cox maximum likelihood analysis, λ was estimated for each year. The yearly estimates of λ range from -0.09 to 0.21. A value of $\lambda = 0$ implies that a semi-log specification is best, and $\lambda = 1$ indicates a linear form is preferred. Confidence intervals for λ were also estimated. The hypothesis that $\lambda = 1$ could be rejected for every year. Although the hypothesis that $\lambda = 0$ could be rejected for most years,[8] the estimates of λ are always close to zero. Given this limited analysis of functional form, the semi-log specification below is reported:

$$\ln P(x) = \beta_0 + \Sigma \beta_i x_i + \varepsilon . \tag{12}$$

Where P is the sale price of the home, the x_i's are the various attributes of the house, and ε is a white noise error term.

VI. The Data Set

The data set includes over 200,000 observations with variables describing price and attributes of all single-family, detached homes sold over the period 1979 to 1995 in Dallas County, Texas (Dallas County Appraisal District). Each observation includes information about the sale price[9] of the homes and different variables which affect the sale price, including house, neighborhood and environmental quality attributes. As usual, housing quality is described by the square footage of living space, number of bathrooms, lot size, and dummy variables indicating the presence of a pool, central air conditioning, house condition and similar variables. Neighborhood quality is based upon variables such as percent below the poverty level, school quality, ethnic composition and accessibility to the Dallas-Ft. Worth airport, the Dallas central business district (CBD) and the Galleria Mall. Environmental quality is described by proximity to the RSR lead smelter and three other sites. (Other environmental indicators, e.g., air and water quality, do not vary by location and were not included in this study). Using a Geographic Information Systems (GIS) database, Dallas County was set up as a grid of X and Y coordinates. Coordinates were assigned to each house, the airport, the CBD, the Galleria Mall, and selected hazardous waste sites. Distance could then be calculated between any two points. The GIS database was also used to link each house to its census tract (and the corresponding demographic information) and its school district. A media variable was created from a stratified random sample of issues of the *Dallas Morning News* in each year. From the newspaper issues sampled in each year, the media variable is equal to the number of newspaper articles about the RSR smelter site, weighted by inverse of the page number of the start of the article. A description of the variables used in the analysis and descriptive statistics are provided in Table 1.

The most important and publicized of the contaminated sites included in this study is the RSR lead smelter. The RSR lead smelter is located in the central portion of Dallas County, approximately six miles west of the CBD. The smelter operated from 1934 to 1984 and was purchased in 1971 by the RSR Corporation. The smelter emitted airborne lead, which contaminated the soil in the surrounding areas. Lead debris created by the smelter was used in the yards and driveways of some West Dallas residences. In 1981, the EPA found health risks, and RSR agreed to remove any contaminated soil in the neighborhoods surrounding the RSR site using standards that were considered protective of human health at the time. In 1983 and 1984, additional controls were imposed by the City of Dallas and the State of Texas. In 1984, the smelter was sold to the Murmur Corporation who shut the smelter down permanently. In 1986, a court ruled that the cleanup was complete.

In 1991, the Center for Disease Control (CDC) lowered the blood level of concern for children from thirty to ten micrograms of lead per deciliter of blood. Low-level lead exposure in childhood may cause reductions in intellectual capacity and attention span, reading and learning disabilities, hyperactivity, impaired growth, or hearing loss (Kraft and Scheberle, 1995). Also in 1991, the State of Texas found hazardous waste violations at the smelter. In 1993, the RSR smelter was placed on the Superfund National Priorities List (NPL).

Three other contaminated sites are also included in our analysis. These additional sites were selected on the basis of relative importance and proximity to active housing markets in the region. Each of these sites was listed on the EPA's Comprehensive Environmental Response, Compensation, and Liability Inventory List (CERCLIS) during the study period, and none was cleaned up or removed from CERCLIS during the study period. Information about these sites is presented in Table 2.

VII. Estimation Methods and Empirical Results

The analysis covers the impact of the smelter on property values over four event-driven time periods: (1) pre-1981, when the smelter operated but health risks were not officially identified nor publicized; (2) 1981-86, when health risks from soil contamination were officially identified, cleanup was initiated and a Court ruled cleanup was completed; (3) 1987-90, after cleanup was ruled completed; and (4) 1991-95, when new concerns arose and additional cleanup occurred. Slovic *et al* (1991) provides support for the use of event-driven time periods. They write, "Social amplification [of risk] is triggered by the occurrence of an adverse event."[10] Kiel and McClain (1995) also divide their data into event-driven time periods in order to analyze the effect of changes in information over time about an incinerator siting on property values.

In addition to considering division by event-driven time periods, Chow Tests were performed to evaluate whether structural changes occurred. The results indicate that almost every year is significantly different from the previous one. The exception is that the data from sales in 1993 was not significantly different from the data from sales in 1994. In addition, Wald Tests for structural change, which do not assume that the disturbance variance is the same across regressions were performed to test if the event-driven periods are the same. The results indicate that each period is significantly different. In order to partially control for the differences across years within the event-driven time periods, dummy variables are included to the indicate year of sale.

Distance Model Estimation Results: We estimated the standard distance model given by Equation 12. The estimation results are presented in Table 3. The estimated coefficients have the expected signs and are statistically significant in each period, with only a few exceptions. Our first hypothesis is that people pay a premium for distance from the RSR Smelter. This hypothesis can be rejected if the estimated coefficient for the distance variable is not significantly greater than zero. The price gradient starts out significantly positive before the EPA identification of the RSR site and during cleanup of the site, indicating that a buyer is willing to pay a premium for a location which is farther away from the RSR site. The positive sign on distance before EPA identification could be interpreted to mean that effect of the RSR site is already capitalized in property values in the 1979-1980 time period. However, after cleanup, this coefficient turns significantly negative. This differs from the expected sign of the distance coefficient, which is either positive or zero. There are a number of explanations for the negative sign in a straight distance model estimation.

The most compelling explanation for the negative sign on the distance coefficient after cleanup is that sphere of influence of the smelter is limited. This issue is explored with an examination of the continuity price gradient and a comparative analysis of the smelter area and a control area. Another possible explanation for the negative coefficients is that before identification, houses were sold as close as 0.17 miles from the RSR site. In the period after cleanup (1987-1990), no houses within a mile of the RSR site were sold.[11] Therefore, in the first post-cleanup period (1987-1990), the discounted houses within one mile of the smelter no longer affect the coefficient on the distance variable.

Our next hypothesis is that the coefficient on distance does not change over the different event-driven time periods. This can be tested using F-tests. This hypothesis is a crude test of the duration of stigma.[12] For example, if the coefficient on distance starts out positive, and then after remediation it is no longer positive, stigma is not permanent. Our results indicate that the coefficients on distance are significantly different in each of the four periods.

Continuity of the Price Gradient: Previous studies, such as McClelland, *et al.* (1990), have found that the impact of the waste site on property values dissipates rapidly with distance. Following Thayer, *et al.* (1992), two sets of estimations were completed to allow for discontinuity of the price gradient. First, the continuous distance variable was converted into five discrete indicator variables for distance, ranging from less than one mile to greater than four miles, in one-mile increments. These distance dummy variables were used in place of an intercept term in the hedonic regressions. The next distance models that were estimated include a linear spline function on distance, which allows for a discontinuity in the price gradient. The linear spline allows for there to be one premium for distance up to a critical point and then an adjustment to the premium after that point.

We tested the hypothesis that the effect of the smelter is constant with distance. Intuitively, we conjectured that the marginal premium paid for distance from the smelter will dissipate with distance. Using the discrete distance model, the hypothesis can be rejected if the coefficients on distance are significantly different from each other. The estimated coefficients on the discrete distance dummy variables are presented in Table 4. In each period, the intercept for houses sold within a one-mile radius of the RSR site is significantly less than the others, with the exception of the first post-cleanup period (1987-1990) when there were no sales within one mile of the RSR site.

The second set of estimations involved a linear spline function. Formally, let x_1 be the distance to the site, let x_2 be the distance at which the influence of the site diminishes, and let x_3 to x_n be the other attributes of the house. The linear spline can be represented as

$$(13) \qquad P(x) = \beta_0 + \beta_1 x_1 + \beta_2 d_2 (x_1 - x_2) + \sum \beta_i x_i \, .$$

Where $d_2 = \begin{cases} 1, & if\ x_1 > x_2 \\ 0, & otherwise \end{cases}$.

This model was estimated twice allowing for a discontinuity in the price gradient at both one mile and four miles.[13] The estimation results with a linear spline function with critical points at one and four miles are presented for the distance coefficient, β_1, and the adjustment coefficient, β_2, in Table 5. The hypothesis that the effect of the smelter is constant with distance can be rejected if the coefficient on the adjustment variable is significantly different from zero. The coefficients on the adjustment variable are significantly different from zero in each period both for the one and four mile critical points.[14]

The duration of stigma in close proximity to the smelter can be tested again while allowing for a discontinuity in the price gradient. The coefficients on the distance variable are significantly different in each of the four periods. The price gradient for a distance of four miles or less starts out positive before the EPA identification of the RSR site and during cleanup of the site. After cleanup, this coefficient turns negative when the critical point is set at four miles. However, when the critical point is set at one mile from the RSR site, in the second period after cleanup (1991-1995), the coefficient on distance less than one mile from the RSR smelter is significantly positive, which indicates that there is a post-cleanup stigma within a very limited (no greater than one mile) sphere of influence.

Control Area verses Smelter Area: In order to isolate causality, a comparison between the smelter area and the control area is made. Two statistical models with an indicator variable were estimated, and the estimated coefficients for the indicator variable are reported in Table 6. The first statistical models has an indicator variable which is equal to one when the distance from the smelter is less than four miles and zero otherwise. The second incorporates an indicator variable which is equal to one when the distance from the smelter is less than one mile and zero otherwise. The rest of Dallas County is an appropriate control area because housing price trends in metropolitan Dallas were not in sync with other metropolitan areas of the U.S. (Abraham and Hendershott, 1996).

The tested hypothesis is that a location in the smelter area has no effect on property values. This hypothesis can be rejected if the coefficient on the smelter area indicator variable is significantly different from zero. The coefficient on the smelter-area location variable is negative and significant in the period before EPA identification of the smelter (1979-1980) for both a one-mile and four-mile radius smelter area. This means, of course, that homeowners received a discount for a smelter location. The magnitude of the discount increased in the period in which EPA identification and cleanup of the RSR smelter occurred (1981-1986). In the first post-cleanup period, the coefficient on the smelter-area location variable becomes slightly positive for the four-mile radius smelter area. However, there were no sales within one mile of the smelter during that period. This means that the houses within one mile of the smelter are no longer affecting the smelter area coefficient, and these houses are the ones likely to be the most stigmatized. In the second post-cleanup period in which there were new concerns about the smelter area, the coefficient on the smelter-area location variable again becomes negative and significant for the four-mile radius. We note that the discount for a location within one mile of the smelter is higher than the discount for a location within four miles of the smelter in each period (about three times as high in the period 1979-1980, almost eight times as high in the period 1981-1986, and about ten times as high in the period 1991-1995).

Effect of the Media: Gayer *et al.*'s (1997) analysis of risk tradeoffs at superfund sites includes a news variable based on Superfund newspaper coverage in a regional newspaper. They find that their news variable has a negative and significant effect on property values. A media variable was also created from a random sample of two issues per month of the *Dallas Morning News* in the years 1979-1995 for a total of 408 issues sampled.[15] In our analysis, newspaper coverage serves as a proxy for media coverage. We acknowledge that in recent decades television coverage as a source of news has grown in importance relative to newspaper coverage. However, we justify our use of newspaper coverage because its content tends to be correlated with television coverage. A variable representing television coverage would be extremely difficult to obtain.

As Johnson (1988) points out, the impact of the media coverage depends on how prominently it is displayed. Johnson uses column inches of coverage to account for the differing impact of articles. Gayer *et al* (1997) uses the number of words on coverage to account for different impacts. In this analysis, we constructed a media variable by weighting each article to equal one plus the inverse of the page number of the start of the article. The weighted sum of articles during a given year is the media variable for that year. The media variable for year *t* is can then be expressed as the following

$$media_t = \sum_i article_i \left(1 + \frac{1}{\text{page number}_i}\right) \tag{14}$$

where $article_i$ is any article about the RSR hazardous waste site found in the sample issues in year *t*, and *page number*$_i$ refers to the page number at the start of $article_i$. Alternative methods of weighting articles should be correlated because front-page articles tend to be longer, while shorter articles are often buried in the back of the newspaper. In the period before EPA identification of the RSR site, there was no newspaper coverage in the sample. The bulk of the coverage occurred in the period in which identification of the site and cleanup occurred (1981-1986).

In order test whether the effect of the media on property values is different in the smelter area compared to the control area, two separate regressions are estimated for each time period, and the coefficients on the media variable are compared across the two regressions. The results indicate that the estimated coefficient on the media variable in this time period was negative and significant for properties sold within four miles of the RSR site, while the estimated media coefficient was positive and significant for properties sold greater than four miles away from the site. This is exactly what one would expect to be the case if increased media coverage caused people to choose not to live in close proximity to the smelter site but stay within Dallas County. Media coverage again increased in the period of new concern after cleanup (1991-1995). The media variable coefficient was again negative and significant for properties sold within the smelter area, while it was positive but insignificant for properties sold greater than four miles from the smelter. These findings could indicate an arbitrage away from controversy.

VIII. Conclusion

In this paper, we used a simple theoretical model with external economies and adjustment costs to show that it is possible to arrive at either a permanent stigma equilibrium or a recovery equilibrium after the detection and cleanup of a hazardous waste site. If the recovery equilibrium is the one that eventually emerges, there will only be a temporary stigma on property values. In our empirical analysis, we analyzed whether a stigma equilibrium or a recovery equilibrium emerged for the residential properties in close proximity to the RSR hazardous waste site in Dallas, Texas. We tested several hypotheses regarding the existence and duration of stigma in order to determine which equilibrium emerged in the residential area surrounding the RSR hazardous waste site by estimating a hedonic price model over time using data from individual housing sales prices in Dallas County, Texas.

Our empirical evidence shows that permanent stigma exists in a very limited area. The sphere of influence of the smelter is no larger than a circle around the smelter with a one-mile radius. In the years directly following cleanup (1987-1990), no properties were sold within one mile of the RSR site. In subsequent years (1991-1995), properties within one-mile were sold, but at significantly lower prices than properties located farther away from the smelter. We also found that media coverage of the environmental damage caused by the hazardous waste site has a significant effect on property values in close proximity to the site.

Figure 1

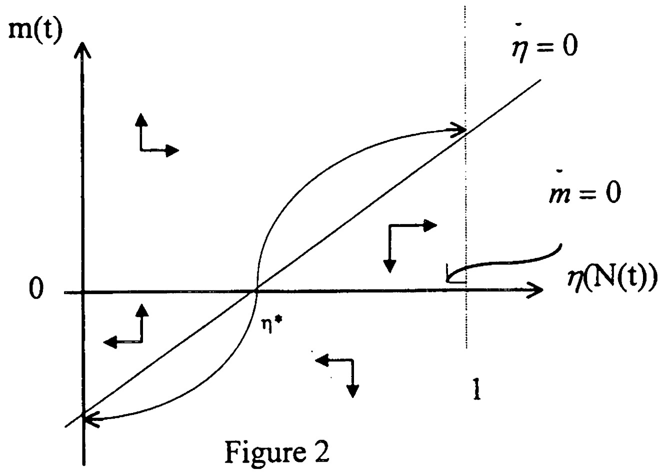

Figure 2

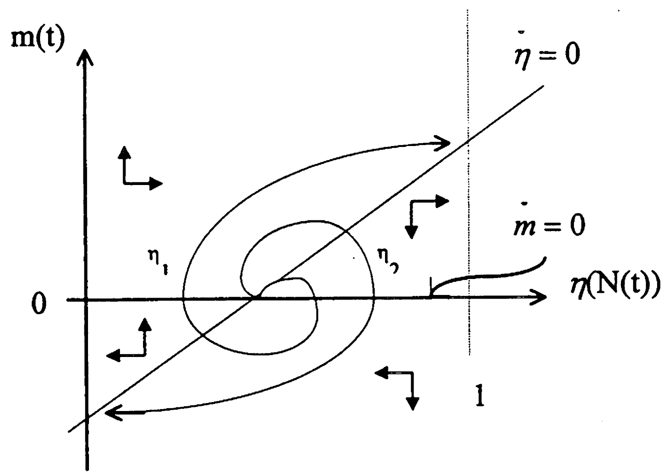

Table 1. Variable Definitions and Descriptive Statistics

Variable	Description	Mean	Std. Dev.
Price	Sales price of the home	104921	98168
Dprice	Deflated sales price of the home	86010	78940
Landarea	Lot size in square feet	9301.87	3969.60
Livarea	Living area in square feet	1797.43	755
Dalcbd	Miles to the Dallas central business district	10.90	3.92
Dfwair	Miles to Dallas/Fort Worth Airport	17.97	6.15
Galleria	Miles to the Galleria shopping center	10.89	5.76
Distsrs	Miles to the RSR facility	11.73	4.22
Age	Age of the house in years	19.97	16.18
Pool	1 if pool, 0 otherwise	0.14	0.34
Garg	1 if attached garage, 0 otherwise	0.87	0.33
Baths	Number of bathrooms	2.03	0.74
Pblack	% of the census track that are African Amer.	11.05	16.98
Phisp	% of the census track that are Hispanic	11.55	13.05
Pbpov	% of the census track below the poverty line	7.68	7.20
Heatcf	1 if central heat, 0 otherwise	0.88	0.32
Accf	1 if central ac, 0 otherwise	0.87	0.33
Good	1 if good condition, 0 otherwise	0.30	0.46
Average	1 if average condition, 0 otherwise	0.68	0.47
Site2	Miles to Site2	13.71	5.36
Site3	Miles to Site3	15.93	69.20
Site4	Miles to Site 4	11.49	5.08
Media	Weighted number of articles in the *Dallas Morning News* about the RSR site	0.60	1.22
	School Districts		
CF	1 if Carrollton/Farmers Branch, 0 otherwise	0.07	0.26
Dallas	1 if Dallas school district, 0 otherwise	0.32	0.47
Cedar Hill	1 if Cedar Hill, 0 otherwise	0.01	0.11
Garland	1 if Garland, 0 otherwise	0.14	0.35
HP	1 if Highland Park, 0 otherwise	0.02	.015
Irving	1 if Irving, 0 otherwise	0.06	0.23
LWH	1 if Lancaster/Wilmer Hutchins, 0 otherwise	0.01	0.11
No district	1 if no district, 0 otherwise	0.07	0.26
MS	1 if Mesquite/Sunnyvale, 0 otherwise	0.04	.021
Coppell	1 if Coppell, 0 otherwise	0.02	0.15
GP	1 if Grand Prairie, 0 otherwise	0.04	0.19
Richardson	1 if Richardson, 0 otherwise	0.13	0.34
Desoto	1 if Desoto, 0 otherwise	0.02	0.15
Duncan	1 if Duncanville, 0 otherwise	0.03	0.18

Table 2. Contaminated Sites Included in the hedonic price analysis

Site	Type of Contamination	Year Listed on CERCLIS	Status
Site1: RSR Smelter	Soil	1981	Court ordered cleanup in 1983
Site2: Superior Site	Ground water	1981	Not contained
Site3: Dallas Naval Weapons Site	Ground water, soil, surface water	1984	Not contained
Site4: Crews Plating Site	Soil	1994	Not contained

Table 3. Distance Model Hedonic Estimation Results

Variable	1979-1980	1981-1986	1987-1990	1991-1995
yr79	9.815 (220.69)	--	--	--
yr80	9.817 (220.76)	--	--	--
yr81	--	9.900 (453.87)	--	--
yr82	--	9.916 (453.35)	--	--
yr83	--	9.966 (457.08)	--	--
yr84	--	9.998 (458.14)	--	--
yr85	--	10.012 (458.25)	--	--
yr86	--	9.961 (455.40)	--	--
yr87	--	--	9.764 (395.14)	--
yr88	--	--	9.653 (390.15)	--
yr89	--	--	9.585 (386.88)	--
yr90	--	--	9.522 (384.40)	--
yr91	--	--	--	8.886 (398.96)
yr92	--	--	--	8.837 (396.70)
yr93	--	--	--	8.816 (395.52)
yr94	--	--	--	8.817 (395.20)
yr95	--	--	--	8.847 (395.40)

Table 3. Distance Model Hedonic Estimation Results (continued)

Variable	1979-1980	1981-1986	1987-1990	1991-1995
Livarea	4.19E-4	4.17E-4	4.07E-4	3.89E-4
	(92.41)	(174.32)	(153.60)	(151.38)
Baths	0.100	0.074	0.069	0.080
	(24.39)	(32.60)	(26.87)	(30.53)
Pool	0.061	0.084	0.104	0.083
	(10.42)	(29.20)	(32.40)	(24.63)
Landarea	2.61E-6	4.32E-6	6.53E-6	8.16E-6
	(5.23)	(16.94)	(19.26)	(29.01)
Garage	0.081	0.083	0.087	0.129
	(19.27)	(31.50)	(24.59)	(37.87)
Central Air	0.091	0.109	0.126	0.185
	(13.30)	(24.99)	(20.69)	32.94)
Heat	0.110	0.087	0.112	0.169
	(15.68)	(19.27)	(17.61)	(28.68)
Good	0.233	0.299	0.455	0.645
	(17.39)	(36.75)	(45.01)	(82.35)
Average	0.166	0.177	0.297	0.441
	(13.17)	(22.35)	(29.87)	(57.81)
Galleria	0.005	0.005	0.001	0.010
	(2.07)	(3.97)	(0.87)	(6.58)
CBD	-0.084	-0.092	-0.043	-0.089
	(-20.54)	(-37.90)	(-14.23)	(-30.30)
DFWAIR	0.015	-0.002	-0.003	0.013
	(4.68)	(-1.54)	(-1.86)	(8.77)
Poverty	-0.008	-0.004	-0.003	-0.005
	(-14.16)	(-14.04)	(-10.01)	(-21.75)
Black	-0.003	-0.003	-0.004	-0.006
	(-17.99)	(-34.67)	(-36.98)	(-56.88)
Hispanic	-0.005	-0.005	-0.007	-0.005
	(-15.16)	(-30.22)	(-40.35)	(-41.57)
Site2	0.043	0.044	0.039	0.06
	(27.85)	(44.54)	(33.88)	(58.36)
Site3	-0.005	0.012	0.034	0.023
	(-1.43)	(6.83)	(18.91)	(13.12)
Site4	-0.021	-0.008	0.011	-0.010
	(-5.95)	(-4.52)	(4.96)	(-4.86)
Distance	0.053	0.033	-0.052	-0.011
	(8.86)	(9.97)	(-13.66)	(-3.08)

Table 3. Distance Model Hedonic Estimation Results (continued)

Variable	1979-1980	1981-1986	1987-1990	1991-1995
School Districts				
Carrollton/	-0.122	-0.111	-0.098	-0.073
Farmers Branch	(-4.09)	(-15.67)	(-16.16)	(-11.58)
Dallas	-0.103	-0.011	-0.017	-0.025
	(-3.45)	(-1.41)	(-2.28)	(-3.27)
Cedar Hill	-0.174	0.078	0.043	0.052
	(-5.23)	(5.89)	(3.64)	(4.73)
Garland	-0.205	-0.096	-0.145	-0.154
	(-6.81)	(-12.32)	(-20.34)	(-22.52)
Highland Park	0.240	0.432	0.301	0.345
	(7.42)	(42.02)	(29.68)	(32.63)
Irving	-0.062	-0.004	-0.080	-0.003
	(-2.06)	(-0.41)	(-8.51)	(-0.30)
Lancaster/	-0.056	0.082	0.036	0.021
Wilmer Hutchins	(-1.76)	(6.84)	(2.86)	(1.82)
Mesquite/	-0.121	-0.008	-0.048	0.013
Sunnyvale	(-3.97)	(-0.97)	(-5.62)	(1.56)
Coppell	-0.095	-0.060	-0.028	0.056
	(-2.56)	(-4.72)	(-2.44)	(5.13)
Grand Prairie	-0.073	0.005	0.017	-0.033
	(-2.28)	(0.40)	(1.41)	(-2.97)
Richardson	-0.117	-0.076	-0.072	-0.078
	(-3.99)	(-10.62)	(-11.16)	(-11.76)
Desoto	-0.025	0.161	0.057	0.110
	(0.80)	(14.89)	(5.50)	(10.99)
Duncanville	-0.051	0.084	0.008	-0.010
	(-1.67)	(8.00)	(0.80)	(-1.07)

Table 4. Estimated Coefficients on Dummy Distance Variables from Discrete Distance Model

Distance from RSR	1979-1980	1981-1986	1987-1990	1991-1995
Less than 1 mile	9.365	8.806	N/A	8.560
	(98.12)	(67.49)		(44.42)
Between 1 and 2 miles	9.899 (178.74)	9.957 (366.12)	9.630 (301.20)	9.082 (305.75)
Between 2 and 3 miles	9.667 (198.25)	9.820 (395.49)	9.492 (321.82)	8.817 (325.08)
Between 3 and 4 miles	9.766 (204.77)	9.885 (410.63)	9.539 (355.86)	8.847 (336.01)
Greater than 4 miles	9.842	9.986	9.508	8.893
	(214.81)	(442.75)	(370.12)	(379.29)

Table 5. Hedonic Estimation Results with Linear Spline Function

Variable	1979-1980	1981-1986	1987-1990	1991-1995
Discontinuity at four miles				
Distance1	0.073	0.065	-0.025	-0.019
	(9.22)	(14.62)	(-4.52)	(-3.61)
adjustment	-0.043	-0.064	-0.048	0.014
	(-3.91)	(-10.75)	(-6.51)	(2.05)
Discontinuity at one mile				
Distance1	0.528	8.329	N/A	2.746
	(2.22)	(8.05)		(1.79)
adjustment	0.477	-8.298	N/A	-2.757
	(-2.00)	(-8.01)		(-1.79)

Table 6. Hedonic Estimation Results, Dummy Variable for Smelter Area Model

Variable	1979-1980	1981-1986	1987-1990	1991-1995
Four-mile radius				
Smelter Area	-0.142	-0.145	0.033	-0.029
	(-14.65)	(-23.95)	(4.07)	(-3.75)
One-mile radius				
Smelter Area	-0.438	-1.06	N/A	-0.291
	(-5.07)	(-7.91)		(-1.48)

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Endnotes

[1] Robert Hall (1994) provides a case study of the effect of contamination on the value of an apartment property. An underground oil spill created unhealthy conditions, which led to a number of tenants leaving. Rents then declined, and the property became "seedy." Even after the spill was cleaned up, the property had substantially declined in value.

[2] Patchin (1991), p. 169.

[3] Exceptions include Kohlhase (1991) and Kiel (1995), who examine property values at more than one point in time, but do not consider post-cleanup property values. Kiel and McClain (1996) examine housing prices before and after a failed incinerator siting. However, for the latter analysis the incinerator was only hypothetical. Dale *et al.* (forthcoming) do consider post-cleanup values, but they do not consider discontinuities in the price gradient on distance.

[4] For additional cites and a comprehensive survey of empirical results, see Farber (1998).

[5] Thayer *et al.* (1992), p. 266.

[6] There is also a third, unstable equilibrium

[7] With perfect markets, renting and owning are equivalent.

[8] The large sample size results in very tight confidence intervals.

[9] Prices were deflated using the shelter housing price index (1982-84=100) from the *Economic Report of the President.*

[10] Slovic *et al.* (1991), p. 685.

[11] The usual explanation for a lack of sales around a locally undesirable land use is that there are no buyers. However, it may also be the case that potential sellers are holding on to their properties with the hope that property values will rise in the future.

[12] The reason that this is a crude test for the duration of stigma is that the price gradient for distance from the smelter will be discontinuous if the sphere of influence of the smelter dissipates rapidly with distance.

[13] Recall that there were no sales with one mile of the RSR smelter in the first post-cleanup period (1987-1990).

[14] The coefficient on the adjustment coefficient for the period 1991-1995 with a critical point of one mile is only significant at the ten- percent level.

[15] The *Dallas Morning News* is not indexed over the entire period of the data set (1979-1995), so the data was obtained by going through microfiche. Consequently, only a random sample of issues was used to construct the media variable.