# Do Landfills Always Depress Nearby Property Values?

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## ABSTRACT

All available hedonic pricing estimates of the impact of landfills on nearby property values are assembled, including original estimates for three landfills in Pennsylvania. A meta-analysis shows that landfills that accept high volumes of waste (500 tons per day or more) decrease adjacent residential property values by 12.9%, on average. This impact diminishes with distance at a gradient of 5.9% per mile. Lower-volume landfills decrease adjacent property values by 2.5%, on average, with a gradient of 1.2% per mile. 20-28% of low-volume landfills have no impact at all on nearby property values, while all high-volume landfills negatively impact nearby values.



Keywords: Landfills, Hedonic Pricing, Nonmarket Valuation, Property Values, Solid Waste

Running Head: Property Value Impacts of Landfills

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## I. INTRODUCTION

Whether, and to what extent, a landfill negatively impacts nearby property values is of interest for several reasons. First, property value differences reveal information about the landfill's welfare impact on nearby households. Second, property owners are keenly interested in knowing the degree to which their asset is or will be devalued by a landfill. Third, estimates of property value impacts can be inputs in a cost-benefit or regulatory impact analysis. In Pennsylvania, for example, the state Department of Environmental Protection is required to consider property value impacts as part of a harms-benefit analysis when making landfill permitting decisions.

Several studies have estimated empirical relationships between residential property values and proximity to a landfill or set of landfills. These studies estimate a hedonic price function, where the price of a house is regressed on both characteristics of the house and its proximity to a landfill. Many of these studies have found that houses located near a landfill sell for lower prices than similar houses located farther away. A widely-cited study is that by Nelson, Generoux and Generoux (1992), who found that property values were depressed within 2 miles of the landfill studied, with an estimated property value gradient of 6.2% per mile.

However, some landfill studies show no statistical relationship between proximity and house price (Gamble et al. 1982; Bouvier et al. 2000; Zeiss and Atwater 1989). Solid waste industry representatives have pointed to these studies as evidence that landfills need not have negative impacts on nearby property values (Parker, 2003). However, each of these studies was based on relatively small samples of house sales, so that the sampling variability in the estimated relationship between proximity and house price was high. It is possible that the landfills studied had negative impacts on nearby property values, but that the relationship could not be statistically identified due to small sample sizes. There has not yet been a large-sample study that conclusively demonstrated small or nonexistent property value impacts from a landfill.

The first purpose of this study is to add to the stock of empirical estimates of the impact of a landfill on nearby property values. A hedonic price function is estimated for a region containing three landfills that differ in size and in their prominence in the landscape. The results show that the three landfills differ in their impact on nearby property values. While two of the three landfills have statistically significant negative impacts on nearby property values, the smallest, least prominent landfill does not. This lack of impact is notable because, in contrast to previous studies that have failed to find a statistically significant impact of landfill proximity on house prices, the regression coefficient on landfill proximity for this landfill is estimated with high precision.

Having demonstrated that property value impacts vary from landfill to landfill, and are in some cases small or nonexistent, the second purpose of this study is to use meta-analysis to investigate factors that might influence the magnitude of the property value impact from a landfill, and to generate a distribution of impacts across landfills. Previous meta-analyses of hedonic pricing studies have focused on identifying a point estimate of the average impact of a class of disamenities (Simons and Saginor 2007, Farber 1998). The meta-analysis conducted here represents an advance in modeling in that it distinguishes between variation among landfills in their house price impacts and sampling error in each estimated impact. In this way, the distribution of house price impacts across landfills is identified. This distribution could serve as a subjective prior distribution for a landfill whose impacts have not yet been measured, or for a proposed landfill that has not yet been built.

*I.A. The Theory of Hedonic Pricing*

The theoretical foundation for empirical analyses of residential property values is based on the work of Rosen (1974). In the context of residential real estate, a single family home is considered as a collection of attributes, characterized as a vector, **z**. The elements of **z** typically include physical characteristics of the house (square footage, age, etc.) as well as characteristics tied to location (proximity to a central business district, school district quality, etc.). The hedonic (or implicit) price function, P(**z**), is the empirical relationship between the market price of a given house and the levels of its attributes. This function describes the equilibrium set of house prices, given the population of buyers and the available housing stock.

The hedonic price function is of policy interest because it reveals information on buyers' preferences over **z**. Buyers search the set of available houses, and choose one that maximizes their indirect utility function, given by V(W-P(**z**),**z**), where W is the wealth of the household. For each single house attribute, $z_i$, the first-order condition for this maximization is

(1) $$\frac{\partial P}{\partial z_i} = \frac{\partial V / \partial z_i}{\partial V / \partial W}$$

The left side of this equality is called the marginal implicit price (MIP) of attribute $z_i$. The right side is the household's marginal rate of substitution between attribute $z_i$ and money. For marginal changes in $z_i$, then, the MIP of $z_i$ measures the household's marginal willingness to pay for additional $z_i$.

The most common approach to estimate the impact of a landfill on property values is to include some continuous measure of proximity to the landfill as one of the elements of **z**. Linear distance is the most common measure of proximity, though inverse distance and natural log of distance have also been used. If $z_i$ measures linear distance to the landfill, then the estimated MIP associated with $z_i$ measures the change in house price associated with a one-unit change in distance to the landfill.

While equation (1) can provide an estimate of a household's marginal willingness to pay to change its proximity to the landfill, it is usually of more interest to consider a nonmarginal change, for example comparing house price in the presence of the landfill to what price would be in the absence of the landfill. If $\mathbf{z}^0$ measures the attributes of a house located near a landfill, and $\mathbf{z}^1$ measures the same house's attributes absent the landfill, then $\Delta P = P(\mathbf{z}^1) - P(\mathbf{z}^0)$ is the impact of the landfill on the property's value. This provides an exact measure of the benefit or cost to the household only if moving costs to relocate are minimal, and the change affects only a small number of houses.[1] If moving costs are substantial, the implicit price function can still provide useful information. Specifically, $\Delta P$ is an upper bound on the household's willingness to pay to remove a nearby landfill, or a lower bound on the amount a household would need to be compensated to accept a new landfill that does not currently exist.

*I.B. Previous Studies of Landfill Impact on Property Values*

Using the approach outlined above, several studies have found that house price was significantly related to landfill proximity. One of the first studies of this type (Havlicek, Richardson and Davies 1971) found that house prices increased $0.61 per foot of distance from landfills in Fort Wayne, Indiana. Similar results were obtained for landfills in Minnesota

(Nelson, Generoux and Generoux 1992, 1997), Baltimore (Thayer, Albers and Ramatian 1992), Columbus, (Hite, Chern and Hitzhusen 2001), and Toronto (Lim and Missios 2003).

Not all studies have found significant positive relationships between distance to the landfill and house price, however. Gamble et al. (1982) estimated hedonic price regressions for house sales near a landfill in Boyertown, Pennsylvania. When the dataset was split and separate regressions estimated by year of sale, the estimated coefficients for distance to the landfill were not statistically significant at the 5% level. One of these estimated implicit prices was even negative, implying higher prices closer to the landfill. This last result has been cited as evidence that modern landfills need not have negative impacts on property values (Cartee 1989, Parker 2003). However, the negative implicit price was estimated with very low precision due to the small sample size (n=45). In a model that pooled observations across years, the estimated coefficient on distance from the landfill was positive and significant at the 10% level, implying that the landfill does depress nearby property values.

Reichert, Small and Mohanty (1992), in a hedonic regression for houses located near a landfill in Cleveland, Ohio, also find that the estimated MIP for distance was negative, implying higher prices near the landfill.[2] Again, this estimated MIP was statistically insignificant, with high sampling variability. The authors argue that the lack of relationship between proximity and house price was due to unmodeled heterogeneity in neighborhood quality. Using a smaller, more homogeneous study area, they find that houses near the landfill sell for $6000-$8000 less than houses farther away.

Bouvier et al (2000) estimate hedonic regressions for houses located near six landfills in central and western Massachusetts, two of which were open and active during the study period. For these two landfills, the estimated MIP of distance was positive for one and negative for the other, but statistically insignificant in both cases. Again, the estimated negative coefficient had high sampling variability due to small sample size.

Zeiss and Atwater (1989) estimate hedonic price regressions for three neighborhoods located near a landfill in Tacoma, Washington. Though they do not report the estimated MIP values, they do report that for two of the neighborhoods, a statistically significant relationship between house price and landfill proximity did not exist. For the third, they find that houses located nearer the landfill have higher prices, but attribute the result to new homes built near the landfill, and not to the landfill itself.

To summarize, most available studies that have included distance from a landfill in a hedonic regression have found a statistically significant positive relationship between house price and distance. While some studies did find that house price and distance from the landfill were not significantly related, in all such cases the estimated MIP has high sampling variability. While these studies could not reject a null hypothesis of no impact, that is not equivalent to concluding that the landfills have no impact on property values. Using the reported standard errors from the original studies, it is possible to construct 95% confidence intervals for each of the statistically-insignificant MIP estimates discussed above. In all cases where a statistically insignificant MIP is reported, a 95% confidence interval for the MIP includes the value 5% per mile. In other words, if we posit a null hypothesis that every landfill has a negative impact on nearby property values with a gradient of 5% per mile, none of these studies would statistically reject that null hypothesis. Thus, no study to date has demonstrated, with statistical confidence, that the impact of a landfill on nearby property values is small (less than 5% per mile).

The remainder of this paper is organized as follows. In Section II, new empirical estimates of the property value impacts are reported for three landfills. In Section III, a meta-analysis of all available landfill property value impact estimates (including the three reported here) is conducted. Section IV discusses the results, and Section V concludes.

## II. PROPERTY VALUE IMPACTS OF THREE LANDFILLS

*II.A. Data and Methods*

The study area is Berks County, in southeastern Pennsylvania. Three landfills are included in the analysis. Western Berks Landfill is small, with a permitted area of 65 acres, and accepted 300-400 tons of waste per day during the study period, mostly from local municipalities. It is located near the City of Reading, but is physically isolated from residential areas by a river and trees, and is difficult to see from off the property. It closed in 2003, after an application to expand and extend its operations was denied. Rolling Hills Landfill is larger (120 permitted acres) and accepts 2,400 tons per day. It is located in a more-rural part of the county, with lower housing density. Topography shields it from view from most directions, but it is visible in some directions from over a mile away. Sixty percent of the material disposed is ash from a solid waste incinerator located in an adjacent county. Pioneer Crossing Landfill had 92.5 permitted acres, and accepted 1,000 tons per day during the study period. It has since been granted a new permit that increases its footprint and its average daily tonnage to 1,550 tons per day. It has had a history of compliance problems, with 58 violations between 1997 and 2000. Since 2000, the frequency of violations has decreased. It is located directly across the river from a densely populated town (Birdsboro). Its height makes it a prominent feature on the landscape, with the working face visible from many residential areas within Birdsboro.

The database of residential sales was constructed from the 2002 digitized parcel map of Berks County maintained by the Berks County Office of Assessment. For each residential parcel sold in an arms-length sale between 1998 and 2002, the location of the house was assumed to be the centroid of the parcel. Mobile homes were excluded from the dataset because it is difficult to determine whether the sale includes built structures. Houses located on lots larger than 5 acres were excluded, to avoid situations where the property has multiple uses or receives preferential use taxation. Properties with lot size less than 0.035 acres, with living area less than 600 square feet, with sale price less than $25,000, or rated as "poor" or "unsound" condition were excluded to avoid unique or difficult-to-value homes. Properties where the sale price diverged from the assessed value by more than 25% were excluded, to avoid situations where the assessor's database did not accurately represent the house at the time of sale.

Information on structural characteristics (square footage, age, lot size, etc.) and the price and date of the most recent sale for each house came from the assessor's database. Based on the house's location, distance to each of the three landfills was calculated, as well as distance to downtown Reading, Philadelphia, and Allentown, the three most important employment centers for the region.[3] Differences in local services and the populations who choose those services are captured by township dummies. School district quality is measured by district average scores on Pennsylvania System of School Assessment (PSSA) standardized tests. Digital elevation models provided information on elevation and average slope at the house, as well as a measure of relative elevation, defined as elevation at the house minus average elevation within 800 meters of the house. Positive values of relative elevation mean that the house sits above the surrounding terrain.

A county-wide map was developed showing the location of all industrial land. Because landfills are a type of industrial land use, proximity to a landfill will be correlated with proximity to industrial land. By including a measure of industrial land near the house, the impact of landfills on house price can be estimated separately from the impact of industrial land (Deaton and Hoehn 2004). For each house, the proportion of land in industrial use within 400 meters of the house, between 400 and 800 meters from the house, and between 800 and 1600 meters from the house was measured.

House sale prices were inflated to real (2002) dollars. The dependent variable in the hedonic price regressions was natural log of real house price. Two regressions were conducted. The purpose of the first regression was to identify the outer limit of each landfill's possible impact. For each landfill, three dummy variables were constructed identifying properties located within three concentric rings of width 1 mile around the landfill. To control for regional differences in the housing markets, dummy variables were included identifying houses within 10 kilometers (6.2 miles) of each landfill. All house price effects reported in the results section are therefore estimated relative to the average house price within 10 kilometers of the landfill.

The purpose of the second regression is to estimate MIP's per mile of proximity for each landfill. The dummy variables are replaced with continuous measures of distance to the landfill. Based on the results of the first regression, an outer limit is placed on the distance within which the landfill impacts house prices. The measure of distance from the house to the landfill takes the form

$$\text{(2)} \qquad \text{Distance Measure} \; = \begin{cases} D & \text{if } D \leq L \\ L & \text{if } D > L \end{cases}$$

where D is the distance from the landfill boundary to the house and L is the outer limit of the landfill's impact, as determined from the first regression. Using this distance measure, the MIP of landfill proximity is constant for all houses within L miles of the landfill, and zero for all houses more than L miles from the landfill.

This study differs from many previous studies in that it includes sales that occur outside the area where house price impacts could be expected. This is done for two reasons. First, additional sales provide additional information about the MIP's for characteristics other than landfill proximity, improving the regression's efficiency. Second, sales outside the area influenced by the landfill provide a baseline, against which sales near the landfill can be compared.

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*II.B. Results*

11,090 house sales were included in the hedonic price regressions, with an average real sale price of $130,700. There were 2,139 house sales within 3 miles of the Western Berks landfill, 952 sales within 3 miles of Pioneer Crossing landfill, and 191 sales within 3 miles of Rolling Hills landfill.

The first regression used dummy variables to identify landfill impacts on house price for concentric rings around each landfill. The estimated coefficients for the concentric ring dummy variables are presented in Table 1. Each of these estimated coefficients represents the percent difference in the price of a house located within that ring compared to a similar house located more than 3 miles from the landfill.[4] Pioneer Crossing Landfill has a statistically significant negative impact on properties located within 1 mile, and on properties located from 1 to 2 miles away, but does not have an impact on property more than 2 miles away. Rolling Hills landfill also has a statistically significant negative impact on house prices within 2 miles. Although the estimated coefficient for the third concentric ring is statistically significant at only the 10% level, its sign and size are consistent with the coefficients for the inner two rings, suggesting that the impact extends beyond 2 miles. Western Berks Landfill does not appear to impact nearby house prices.

Based on the results of the first regression, the outer limit used in the second regression for the house price impact is set at 2 miles for Pioneer Crossing landfill and at 3 miles for Rolling Hills landfill. While Western Berks landfill does not appear to impact nearby property values, a MIP is still estimated with an outer limit of 2 miles, for comparison purposes.

The first regression is also used to determine the spatial limit of any impact from industrial land. Failure to account for the influence of industrial land other than landfills could lead to omitted variable bias in the hedonic price regression. The coefficient on the proportion of land within 400 meters of the house in industrial use was negative and statistically significant (t=7.38), as was the coefficient on the proportion in industrial use between 400 and 800 meters from the house (t=2.66). The coefficient on the proportion between 800 and 1600 meters from the house was not significantly different from zero (t=0.13). Based on these results, the first two measures of industrial land are included in the second regression, but the third is not.

Results from the second regression, with continuous proximity measures, are presented in Table 2.[5] Nominal house prices increased at less than the rate of inflation during the study period, so that real price decreased by about 1.5% per year. Estimated coefficients on structural characteristics were all statistically significant at the 1% level and of the expected sign. House prices increase at a decreasing rate for both living area and lot size. Houses located closer to Allentown and to Philadelphia sold for higher prices, but proximity to Reading was not related to house price. Houses at higher elevation and on more-sloped lots sold for lower prices. Houses situated above the surrounding terrain sold for higher prices. Houses located in school districts with higher average test scores sold for higher prices.[6]

The estimated coefficient on the measure of distance to the landfill is positive and statistically significant for both Pioneer Crossing Landfill (PCL) and Rolling Hills Landfill (RHL), implying that houses nearer those landfills sold for lower prices than similar houses farther from the landfills. The MIP per mile is smaller for Rolling Hills than for Pioneer Crossing, but the impact extends over a longer distance, so that the total house price impact at the landfill boundary (the difference between the price of a house at the landfill boundary and the price of a similar house located outside the landfill's area of influence) is similar. The estimated MIP per mile of proximity for Western Berks Landfill (WBL) is negative, implying higher prices nearer the landfill, but small and statistically insignificant. In contrast to previous studies with statistically insignificant MIP estimates, though, here the MIP is estimated with high precision. A 95% confidence interval for the MIP for Western Berks is (-0.0412, 0.0180).

There is not a statistically significant difference between the MIP per mile for Rolling Hills landfill versus Pioneer Crossing landfill. However, the MIP per mile is significantly lower for Western Berks landfill than for either of the other two landfills. While this is the first large-sample empirical study to demonstrate, with high precision, that the property value impact of a landfill can be small or nonexistent, the result is not surprising. Western Berks is both smaller and less visible than the other two landfills. Many nearby residents are unaware that it even exists (Stahl 2003).

## III. META-ANALYSIS OF LANDFILL IMPACTS

As the results reported above demonstrate, there are real differences among landfills in the MIP per mile. It is therefore not possible to calculate one MIP appropriate for all landfills. In this section, a meta-analysis is conducted for all available MIP estimates. The primary purposes of this meta-analysis are to characterize the mean MIP and its variability across landfills and to explore whether differences among MIP estimates are related to features of the landfills studied or to the methods used in each study.

Table 1 summarizes 15 different MIP estimates from 13 different landfills or groups of landfills, including the three MIP estimates generated in this study. Each MIP estimate is expressed as the percent increase in house price per mile of distance from the landfill.[7] For studies that use natural log of price as the dependent variable, the MIP in Table 1 is the estimated regression coefficient reported in the study, converted to impact per mile. For studies that estimated a linear model, the regression coefficient for distance was divided by the average house price in the dataset.[8] Where average house price is not reported, it is obtained for the study area from secondary sources.

The meta-analysis conducted here differs from previous studies of local disamenities in that it distinguishes between variation among landfills in their MIP and sampling variability in the measurement of each MIP. It is assumed that each landfill has a true MIP given by

(3) $$Y_i = X_i'\beta + \nu_i$$

where $Y_i$ is the true MIP, $X_i$ is a vector that measures characteristics of the landfill and of the study, $\beta$ is a vector of parameters to be estimated, and $\nu_i$ is normally distributed with mean 0 and variance $\sigma_\nu^2$. $Y_i$ is not observed. Instead, each study provides an estimated MIP, $\hat{Y}_i$, that includes some sampling error, so that

(4) $$\hat{Y}_i = Y_i + \varepsilon_i = X_i'\beta + \nu_i + \varepsilon_i$$

where $\varepsilon_i$ is an error term associated with measurement error that is distributed normal with mean 0. The variance of $\varepsilon_i$ varies from study to study based on, for example, sample size. For each study, an estimate of the variance of $\varepsilon_i$ is given by the square of the sampling error for the MIP estimate, $se_i^2$. The value of $se_i^2$ for each study is derived from the reported sampling error for the parameter on distance to the landfill, appropriately adjusted for differences in distance units or for conversion to a percent measure. Assuming that $\nu_i$ and $\varepsilon_i$ are independent, $\hat{Y}_i$ is distributed normally with mean $X_i'\beta$ and variance $\sigma_\nu^2 + se_i^2$.

The parameters of this model, $\beta$ and $\sigma_\nu$, were estimated using maximum likelihood. The likelihood function for the estimation is given by

(5) $$L = \sum_i ln\left[\frac{1}{\left(2\pi\left(\sigma_\nu^2 + se_i^2\right)\right)^{0.5}} exp\left(\frac{-\left(X_i'\beta - \hat{Y}_i\right)^2}{2\left(\sigma_\nu^2 + se_i^2\right)}\right)\right]$$

The following explanatory variables were included in X: sample size in the regression, average house price in the dataset, assumed spatial limit of the impact on house prices (in miles), and volume of waste accepted at the landfill, where available.[9] Of these, only the volume of waste accepted at the landfill was significantly related to the size of the MIP. Specifically, landfills that accepted 500 tons per day (tpd) or more of waste had a significantly higher MIP than those that accepted less waste, with the difference statistically significant at the 5% level.[10] None of the other explanatory variables were significantly related to MIP, either when considered alone or in combination.

Estimation results are presented in the first column of Table 4. For low-volume landfills, the average per-mile property value impact is 1.18%. For high-volume landfills, the estimated average per-mile property value impact is 1.18% + 4.74% = 5.92%. While these represent the best-guess estimate of property value impacts for these two groups of landfills, there is variability among landfills in their impact. The variation among landfills in these impacts is captured by $\sigma_v$, which is estimated to be 2.01.[11] Using these estimates, it is possible to calculate the proportion of landfills in each group that would have zero (or possibly positive) impact on nearby property values, given by $\Phi(-X'\beta/\sigma_v)$. Using the parameter estimates in the first column of Table 4, 28% of low-volume landfills would have zero (or positive) impact on nearby property values, while 72% would have negative impacts. In contrast, 99.8% of high-volume landfills would be expected to have negative impacts on nearby property values.

The studies listed in Table 4 assume different spatial limits for the landfill's potential impact on house price.[12] Combining the estimated MIP per mile with the assumed spatial limit on the impacts provides an estimate of the percent impact that the landfill has on a house located immediately adjacent to the landfill boundary, compared to a similar house located outside the region impacted by the landfill.[13,14] These are presented in Table 3. A second meta-analysis was conducted for these total impact estimates. Again, the total impact on the value of an adjacent property varied depending on the volume of waste accepted at the landfill. The estimated coefficients from this meta-analysis on total impacts are presented in the second column of Table 4. On average, the total impact on the price of a house located adjacent to a low-volume landfill is 2.47%. For a high-volume landfill, the average total impact on an adjacent property's value is 12.91%. Among low-volume landfills, 80.0% are expected to have negative impacts on adjacent property values, while 20.0% have no impact or positive impacts. Among high-volume landfills, the proportion of landfills that are expected to have no impact on adjacent property values is essentially zero ($5.3x10^{-6}$), implying that all landfills that accept higher volumes of waste have negative impacts on adjacent property values.

## IV. DISCUSSION

The results show that landfills do not always depress nearby property values. The estimated MIP for Western Berks landfill was essentially zero, and was estimated with high precision. The meta-analysis of available landfill property value impact studies showed that 20-28% of landfills that accept low volumes of waste have no impact on nearby property values. However, all landfills that accept high volumes of waste have negative impacts on nearby property values.

These meta-analysis results are consistent with previous within-study comparisons of landfills operating at different scales. Lim and Missios (2003) compared two landfills in Toronto, Ont., and found that the landfill that accepted a higher volume of waste had a larger property value impact than the landfill that accepted a lower volume. Similarly, in this study, the two landfills that accepted high volumes of waste had statistically significant negative impacts on nearby property values, while the landfill that accepted less waste did not. The meta-analysis confirms those within-study results, and demonstrates statistically that high-volume landfills do indeed have larger impacts on nearby property values than low-volume landfills.

One would similarly expect that a landfill's prominence on the landscape would help determine whether and how much it impacts nearby property values. The results presented here for the three Berks County landfills were consistent with that conjecture. Anstine (2003) also found that the degree to which a facility impacted nearby property values depended on whether it was visible from the surrounding area. Similarly, Hite (1998) found that only when buyers were aware of the presence of a landfill were property values bid down. Unfortunately, prominence on the landscape could not be included as an explanatory variable in the meta-analysis, because it could not be objectively measured for all landfills. This is an important limitation because less-prominent landfills will tend to be smaller in footprint and accept lower volumes. It may be difficult to disentangle the impacts of prominence and volume accepted. Volume of waste accepted, as measured in this analysis, should therefore be viewed as a proxy variable that captures both scale of operation and prominence on the landscape.

The meta-analysis presented here suffers from the usual limitation that it is confined to published studies. Studies may have been conducted that failed to show an impact on property values where the authors or journal editors chose to not publish the results. To the extent that this "file drawer" bias exists, the results presented here would tend to overestimate the average impact of landfills on property values, and underestimate the proportion of landfills with no impact.

With that caveat, the results of the meta-analysis can provide landfill permit applicants, permitting agencies and local citizens useful information on the potential impact that a landfill could have on nearby property values. In particular, they emphasize the important point that the impact will vary across landfills. Some of this variation can be predicted, depending on the scale of operation of the landfill. However, there will remain some uncertainty over the magnitude of the impact from a landfill. The meta-analysis presented here can be used to generate a distribution of the possible impacts.

## V. CONCLUSION

While most previous hedonic pricing studies have shown that landfills depress nearby property values, some have found no impact. However, previous studies that failed to detect an impact were based on small samples, so that their statistical power to detect a property value impact was limited. A large-sample hedonic price regression was estimated for three landfills in

Pennsylvania. Two large, prominent landfills depressed nearby property values, while a small, inconspicuous landfill had no impact. This last result is the first time that a large-sample study has shown no impact from a landfill on nearby property values.

A meta-analysis was conducted that included all available hedonic price studies of the impact of landfills on nearby property values. It showed that landfills that accept high volumes of waste (500 tons per day or more) have a greater impact on nearby property values than landfills that accept low volumes. On average, a high-volume landfill will depress the value of an adjacent property by 12.9%. This impact decreases with distance from the landfill at a gradient of 5.9% per mile. A low-volume landfill will depress the value of an adjacent property by only 2.5%, on average, with a gradient of 1.2% per mile.

A second important finding of the meta-analysis is that, even within landfill classes, there is important heterogeneity among landfills in their property value impacts. This means that some landfills will have higher than average impact, while others will have lower than average impact. In fact, 20-28% of low-volume landfills will have no impact at all (or possibly a positive impact) on nearby property values. All high-volume impacts will negatively affect nearby property values. The results of the meta-analysis can be used by permitting agencies or local citizens to estimate the range of possible property value impacts from an existing or proposed landfill.

**Endnotes**

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1 If the change affects many or all houses in the market, then the problem is much more complex, because the hedonic price function itself shifts as a result of the change.

2 The result discussed here is for the Westlake landfill. The authors estimate hedonic regressions for five landfills, but report results for only two. For the other regression reported, the Jennings Road landfill, the estimated coefficient on distance cannot be interpreted as a MIP for distance, because the sample includes sales that occurred prior to the opening date of the landfill.

3 For both Philadelphia and Allentown, distance is measured to commuting waypoints, through which most traffic from the county must travel.

4 For a dummy variable, $X_j$, the percent difference in house price for $X_{ij}$=1 verus $X_{ij}$=0 is given by 1-exp(-$\beta_j$), which for small $\beta_j$ is closely approximated by $\beta_j$.

5 To save space, estimated coefficients for dummy variables for township and month-of sale are not reported. Complete results for both hedonic price regressions are available from the author.

6 Regression results for the first regression for variables other than landfill proximity were similar to those presented in Table 2.

7 Some studies are excluded from Table 3 because they used dummy variables to measure proximity, rather than continuous measures, so that calculation of a MIP per mile is not possible. These include Baker (1982); Zeiss and Atwater (1989), and Bleich, Findley and Phillips (1991). Hite, Chern and Hitzhusen (2001) are not included in Table 3 because information needed to calculate an MIP as percent of house price was not available.

8 Because Bouvier et al. (2000) use inverse of distance to the landfill as a measure of proximity, the MIP varies with distance. The estimates in Table 3 are the calculated MIP per mile at a

distance of one mile from the landfill, halfway from the landfill to the outer edge of the study area.

[9] Where daily tonnage was not reported in the original study, it was obtained from secondary sources, usually the state environmental agency. Volume accepted could not be measured for the two studies that included multiple landfills, and they are excluded from estimations that include that explanatory variable.

[10] 500 tpd translates into about 25 long-haul truckloads per day, or about 50 loads using local collection trucks. When tons per day is included as a continuous variable, the estimated coefficient is positive but not statistically significant.

[11] An additional estimation showed that $\sigma_v$ did not vary significantly between high-volume landfills and low-volume landfills, so a common estimate of $\sigma_v$ is used.

[12] Havlicek, Richardson and Davies (1971) do not report a spatial outer limit to their dataset, but do state that the data was collected from "the neighborhood(s) around each of five solid waste disposal sites…" Using a reasonable conjecture for how large these neighborhoods might be, an outer limit of 0.5 miles is assigned to this study.

[13] The model used by Bouvier et al., which measured proximity using inverse distance, is undefined at the landfill boundary. For that study, the total impact is measured at ¼ mile from the landfill boundary.

[14] If the study area for a hedonic regression is smaller than the area impacted by the landfill, the total impact estimates listed in Table 3 will be smaller than the true total impact of the landfill.

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Table 1. Landfill Price Impacts within Concentric Rings[a]

| | Pioneer Crossing | Rolling Hills | Western Berks |
|---|---|---|---|
| Within 1600 m | -0.10779 | -0.16532 | 0.01341 |
| | (5.52) | (3.50) | (0.67) |
| 1600 to 3200 m | -0.07247 | -0.10083 | 0.01864 |
| | (5.36) | (2.88) | (1.86) |
| 3200 to 4800 m | 0.01591 | -0.02926 | 0.01803 |
| | (1.64) | (1.85) | (2.36) |

[a] t-statistics in parentheses.

Table 2. Hedonic Price Regression Results

| Explanatory Variable | Units | Parameter Estimate | Standard Error | t-Stat |
|---|---|---|---|---|
| Intercept | | [a] | | |
| Year of Sale | | | | |
| Sold in 1999 | 1=yes | -0.01278 | 0.00400 | -3.19 |
| Sold in 2000 | 1=yes | -0.02777 | 0.00400 | -6.93 |
| Sold in 2001 | 1=yes | -0.03175 | 0.00422 | -7.53 |
| Sold in 2002 | 1=yes | -0.05856 | 0.0332 | -1.76 |
| Structural Characteristics | | | | |
| Living Area | sq. feet | 0.0003205 | 0.0000090 | 35.46 |
| Living Area Squared | Sq. feet | -1.531E-08 | 1.586E-09 | -9.65 |
| Lot Size | Acres | 0.26951 | 0.00785 | 34.33 |
| Lot Size Squared | Acres | -0.04698 | 0.00196 | -23.97 |
| # Bedrooms | # | 0.01890 | 0.00275 | 6.86 |
| # Full Bathrooms | # | 0.06444 | 0.00410 | 15.73 |
| # Half Bathrooms | # | 0.02944 | 0.00377 | 7.81 |
| Basement | 1=yes | 0.08354 | 0.00669 | 12.49 |
| Stone Exterior | 1=yes | 0.17782 | 0.01222 | 14.55 |
| Brick Exterior | 1=yes | 0.05597 | 0.00458 | 12.21 |
| Masonry Exterior | 1=yes | 0.04025 | 0.00551 | 7.30 |
| Central Air Conditioning | 1=yes | 0.05603 | 0.00441 | 12.71 |
| Physical Condition | (1=Exclnt., 4=Fair) | -0.07948 | 0.00604 | -13.16 |
| Detached | 1=yes | 0.12956 | 0.00676 | 19.16 |
| Age of House | years | -0.00401 | 0.00024 | -16.76 |
| Age Squared | years | 0.0000031 | 0.0000022 | 1.38 |
| Neighborhood Variables | | | | |
| Distance to Reading | miles | 0.00171 | 0.00216 | 0.80 |
| Distance to Allentown | miles | -0.00547 | 0.00187 | -2.92 |
| Distance to Philadelphia | miles | -0.00338 | 0.00197 | -1.72 |
| Slope at House Site | % | -0.00371 | 0.00080 | -4.64 |
| Elevation at House Site | meters | -0.000432 | 0.000073 | -5.92 |
| Relative Elevation | meters | 0.00291 | 0.00017 | 17.60 |
| Average PSSA Test Score | no units | 0.00780 | 0.00112 | 6.95 |
| Within 10km of PCL | 1=yes | 0.01553 | 0.01598 | 0.97 |
| Within 10km of WBL | 1=yes | 0.02974 | 0.00892 | 3.34 |
| Within 10km of RHL | 1=yes | 0.04468 | 0.01029 | 4.34 |
| Industrial Land within ¼ mi | % | -0.23728 | 0.03295 | -7.20 |
| Industrial Land ¼ to ½ mi | % | -0.09586 | 0.03338 | -2.87 |
| Landfill Proximity | | | | |
| Distance to PCL (2 mi limit) | miles | 0.10860 | 0.01417 | 7.66 |
| Distance to WBL (2 mi limit) | miles | -0.01159 | 0.01511 | -0.77 |
| Distance to RHL (3 mi limit) | miles | 0.07209 | 0.01782 | 4.04 |

[a] Coefficients for intercept, township dummies and month of sale dummies available from the author

Table 3. Review of studies estimating landfill house price impacts.

| Study | Location | Landfill | Sample Size | Outer Limit of Impact (miles) | Waste Volume (tpd) | House Price Impact per Mile (MIP) % | S.E. | LF Boundary vs Outer Limit % | S.E. |
|---|---|---|---|---|---|---|---|---|---|
| Havlicek, Richardson and Davies | Fort Wayne, IN | various | 182 | 0.5 | n.a. | 19.76 | 9.07 | 9.88 | 4.54 |
| Gamble et al. | Boyertown, PA | Boyertown | 137 | 1 | 200 | 6.70 | 3.81 | 6.70 | 3.81 |
| Nelsen, Genereaux and Genereaux (1992) | Ramsey, MN | Anoka | 708 | 2 | 500 | 6.20 | 1.47 | 12.40 | 2.94 |
| Nelsen, Genereaux and Genereaux (1997) | Eden Prairie, MN | Flying Cloud[a] | 436 | 3 | 1200[d] | 2.64 | 1.11 | 7.91 | 3.33 |
| | | Flying Cloud[b] | 143 | 3 | 1200[d] | 4.32 | 1.19 | 12.95 | 3.58 |
| | | Flying Cloud[c] | 65 | 3 | 1200[d] | 8.43 | 3.21 | 25.30 | 9.62 |
| Lim and Missios | Toronto, Ont. | Keele | 331 | 1.9 | 7671 | 3.65 | 1.83 | 6.93 | 3.48 |
| | | Britannia | 1139 | 1.9 | 456 | 2.21 | 0.96 | 4.21 | 1.82 |
| Thayer, Albers and Rahmatian | Baltimore, MD | various | 2323 | 7.6 | n.a. | 1.30 | 0.51 | 9.41 | 3.50 |
| Reichert, Small and Mohanty | Cleveland, OH | Westlake | 573 | 1 | 155. | -0.87 | 5.62 | -0.87 | 5.62 |
| Bouvier et al. | Massachusetts | Hudson | 47 | 2 | 248 | 2.80 | 4.86 | 9.34 | 15.71 |
| | | Ware | 67 | 2 | 5 | -0.73 | 3.09 | -2.59 | 11.18 |
| This study | Berks Cty, PA | Pioneer Crossing | 11069 | 2 | 1000 | 10.86 | 1.42 | 19.52 | 2.28 |
| | | Rolling Hills | 11069 | 3 | 2400 | 7.21 | 1.78 | 19.45 | 4.32 |
| | | Western Berks | 11069 | 2 | 350 | -1.16 | 1.51 | -2.34 | 3.09 |

[a] low-priced homes; [b] medium-priced homes; [c] high priced homes, [d] estimated.

Table 4. Estimation results.

| Parameter[a] | % Impact per Mile (MIP) | % Impact at LF Boundary |
|---|---|---|
| Intercept ($\beta_0$) | 1.18 | 2.47 |
| | (1.84) | (2.79) |
| High Volume ($\beta_1$) | 4.74 | 10.44 |
| (≥500 tpd)) | (2.09) | (3.47) |
| Std. Dev. ($\sigma_\nu$) | 2.01 | 2.93 |
| | (0.90) | (2.16) |

[a] standard errors in parentheses