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Introduction

With increasing public awareness of the risks from landfill disposal sites, the siting of new landfills has become not only technically difficult but, in some cases, socially and politically infeasible. Waste disposal practices create external costs for nearby residents who are affected by the associated risks from landfills. Examples of such costs include ground and surface water contamination, truck traffic, noise, odor, litter, as well as other nonmarket costs not borne by waste disposal firms and producers of garbage. From an economic perspective, external costs result in an inefficient allocation of resources (too much wastes and exposure). In the absence of statutes and regulations pertaining to landfill disposal, the profit maximizing firm would have little incentive to reduce wastes or public exposure to a socially optimal level.

The question policymakers are now asking is whether the benefits of protecting the public from the risks of landfill disposal justify the costs of such action. Past studies that have estimated the possible damages to human health from landfill wastes provide only a partial analysis of the total cost to society of landfill practices (Raucher, 1983; 1986). A complete analysis should include nonhealth costs such as odor and litter when estimating the costs of siting a landfill in close proximity to rural residential areas.

The landfill disposal issue has been at the forefront in Knox County, Tennessee. In 1987, the Knox County Commissioners denied a permit request by Browning Ferris, Inc. (BFI), to build a landfill in the Carter community of East Knox County. The new landfill siting problem was exacerbated by the fact that the capacity of existing landfills serving Knox County was expected to be depleted in the near future. Even though BFI's permit request was denied, the courts may ultimately decide whether the BFI application conforms to state and local landfill regulations and should thus be approved.

The demand for environmental quality is broadly based, although monetary benefits are subject to strong income and socioeconomic constraints (Mitchell and Carson, 1985). Policymakers have been reluctant to move from the status quo toward incentive-compatible environmental improvements without detailed information about the gainers or losers from a policy change. Therefore, in determining the costs of an externality or the benefits of waste disposal firms internalizing these costs, it would also be politically important to determine the relationship between the socioeconomic characteristics of the effected population and the level of external costs.

The objective of this study was to investigate the relationship between socioeconomic characteristics of Carter community residents and the level of external costs perceived by them if the BFI proposed landfill were to be approved. The remainder of this paper is organized as follows. First, the theoretical basis for estimating external costs of environmental quality deterioration is discussed. Second, the contingent valuation method is reviewed. Third, a regression model is specified relating the costs of siting a landfill in the Carter community to the socioeconomic characteristics of residents. Fourth, data collection methods are described. Fifth, regression results are presented. Finally, policy implications are drawn.

Theoretical Basis

The theoretically appropriate welfare measure for evaluating a change in an environmental amenity is the Hicksian compensating surplus, a measure of willingness to pay for the change in welfare (Hoehn and Randall, 1983; Randall and Stoll, 1983). The modeling of this process is based on microeconomic theory of utility maximization (Varian, 1978).

The value that a person places on an environmental amenity is reflected in the person's utility function:

(1) $U^o = U^o(X, Q)$,

where U^o is some initial level of utility from which a change in welfare is measured, X is a vector of quantities of private goods, and Q is the level of environmental quality with the landfill.

Assume initially that BFI has permission to build a landfill in the Carter community. Now consider the policy option to restrict the landfill. To value this change, one could look at the associated dual minimization problem for the utility function given in (1). The objective in the dual is to minimize total expenditures needed to maintain a given level of utility. This minimum level of expenditures can be obtained by solving the following problem:

(2) Minimize $\Sigma P_i X_i$ subject to $U^o = U^o(X, Q')$

where P_i is the price of private good i, X_i is the quantity of private good i, U^o is the initial level of utility with the landfill, and Q' is the level of environmental quality without the landfill. The solution to this problem defines a cost function E^o:

(3) $E^o = E^o(P_i, Q', U^o)$

By duality, this minimum level of expenditures will also define the consumer's postpolicy income level (Varian, 1978). In this case,

(4) $E^0(P_i, Q', U^0) = M'$

where M is the consumer's income level after the policy decision to restrict the landfill, holding U at U^0, and

(5) $U^0 = U^0(P_i, M', Q')$

which is the indirect utility function defined by the dual utility maximization problem (Varian, 1978).

Thus, the expenditure minimization problem given in (2) enables consumers to implicitly solve for the minimum postpolicy level of income M needed to maintain their initial utility level given the change in Q. The change in income required to maintain the consumer's initial level of utility when Q changes to Q' can be defined as:

(6) $V_i = M^0 - M$,

where M^0 is the consumer's level of income with the landfill and M' is the consumer's level of income without the landfill. In the Carter landfill case, V,,represents the maximum amount a resident would be willing to pay to avoid the landfill. This amount can be viewed as the value a resident places on not having a landfill located nearby or, alternatively, it can be viewed as the external cost to a resident of having a landfill located nearby. At V, the resident would be indifferent to the landfill (Varian, 1978).

Contingent Valuation Method

The costs incurred by Carter community residents can most effectively be estimated using the Contingent Valuation Method (CVM). In CVM surveys, respondents are confronted with a well-defined hypothetical situation (a contingent market); then they are asked to reveal their personal valuations of changes in an unpriced good in the contingent market.

The CVM has been the subject of considerable scrutiny since its development by Davis (1963). Much of the criticism of CVM focuses on survey administration and design problems (Cummings, et al., 1984). However, the most purported weakness is that it is generally not possible to observe whether people would actually pay their stated amount for the change in environmental quality (Bishop, et al., 1984; Freeman, 1986). The hypothetical nature of the CVM could lead respondents to bid carelessly, or strategically for their own perceived benefit, thereby generating unreliable data. Bishop, et al. (1984), speculate that CVM systematically understates willingness to pay to avoid a change (WTP) and overstates willingness to accept compensation for a change (WTA). While there is no doubt that designing and implementing a meaningful and unbiased CVM survey is a challenging task, Randall (1983) argues that "contingent valuation works better than most economists might have expected." Smith, et al. (1985), point out that if careful procedures are followed to develop the questionnaire, to select the sample, and to obtain the completed interview, the respondents will be able to objectively value reductions in their risks to hazardous wastes.

Regression Model Specification

A household's willingness to pay (external cost of the landfill to that resident) is hypothesized to be a function of the household's socioeconomic characteristics and a random error term, stated as:

$$(7) \quad V_i = f(NIH_i, AGE_i, SEX_i, INC_i, EDU_i, HOM_i, YIC_i, DWS_i, MFL_i, POR_i) + e_i, \quad i = 1...n,$$

where i is a subscript representing an individual household, V is annual willingness to pay to avoid a landfill, NIH is number in household, AGE is age of respondent, SEX is sex of the respondent, INC is annual household income, EDU is education of the respondent, HOM is ownership of property, YIC is number of years of residence in the Carter community, DWS is dependence on a well or a spring as a drinking water source, MFL is miles from the proposed landfill site, and POR is perception of risk from the proposed landfill.

The number of persons in a household (NIH) is expected to be negatively related to WTP. This relationship is hypothesized because as household size increases, with household income held constant, per capita income declines, thereby reducing the household's ability to pay. NIH could also have a positive effect on WTP if additional individuals cause an increase in the respondent's concern over the possible effects of having a landfill nearby. The negative effects on WTP of declining per capita income are expected to outweigh the positive effects of increased concern from adding more individuals to the household.

Age (AGE) and sex (SEX) of the respondent are included in the equation to test the hypothesis that these demographic characteristics are important in determining a respondent's WTP. Hypotheses about the relative magnitudes of these variables are not specified a priori.

A household's income (INC) is expected to be positively related to WTP. As household income increases, per capita income increases (NIH constant), increasing a household's ability to pay to avoid having a landfill nearby.

More educated (EDU) respondents are hypothesized to be willing to pay more than less educated respondents because it is more likely that they will be aware of and interested in the environmental implications of landfills.

Those respondents who own their homes (HOM) are expected to be willing to pay more to avoid a landfill than renters. Homeowners would be worse off than renters if property values declined because of the landfill. As a consequence, they might be willing to pay more to avoid the landfill than renters, ceteris paribus.

Willingness to pay is expected to be positively related to the number of years (YIC) a respondent has lived in the Carter community. Those who have lived there longer would more likely be involved in community affairs and would be less mobile than those who have lived there for shorter periods of time.

One consequence of having a landfill located in the Carter Community is the possible contamination of drinking water originating from wells and springs. It is hypothesized that households obtaining drinking water from wells or springs (DWS) would be willing to pay more to avoid the possible contamination of their drinking water supplies from landfill leachate than those who receive water from a municipal source.

The prospect of being adversely affected by a landfill diminishes with distance. Thus, MFL is expected to be negatively related to WTP.

Finally, respondents were asked to rate their perceptions of risk (POR), or level of concern over the proposed landfill, on a scale of one to five with one representing the greatest concern. Those respondents with the greatest perception of risk were expected to be willing to pay more than those with less concern over the landfill's location.

Data Collection

The Carter population was defined as encompassing four Knox County tax maps (numbers 62, 63, 73, 74). An estimated population size of 800 households was derived by reviewing property records for the Carter community in the Knox County Tax Assessors Office. The geographical size of the area (the four tax maps) was approximately eight square miles encompassing the proposed Carter landfill.

A sample of 150 households was randomly selected from the Carter community. Since one objective of the survey was to obtain household willingness to pay, the contingent market in the questionnaire was personally explained to the respondent with the request that the head of household or both spouses jointly determine the WTP value. As Smith, et al. (1985), suggested, careful consideration was given to ensure that respondents were able to understand and evaluate the hypothetical environmental amenity in the contingent market.

In an effort to minimize starting point bias, the researcher elected to use an open-ended question rather than a bidding procedure to elicit WTP values. To aid respondents in understanding and relating to the contingent market, they were given payment cards as developed by Carson (1985). For different levels of income, respondents circled a value from zero to a predetermined number indicating their willingness to pay to avoid a landfill near their residence.

To mitigate the possibility of upward strategic bias, the willingness to pay measure (WTP) as opposed to the willingness to accept compensation measure (WTA) was used to determine the external cost of the landfill to Carter community residents. It should be noted that the WTP value is a conservative estimate of the external cost to Carter residents because of possible downward strategic bias.

Results

Ordinary least squares was used to estimate the relationship between WTP and the hypothesized explanatory variables (equation 7). The results are presented in Table 1. All explanatory variables were 0,1 dummy variables, and the regression coefficients represent deviation from the deleted category. For example, the number in household (NIH) variable included four 0,1 dummy variables: NIH1 (one to two), NIH2 (three to four), NIH3 (five to six), and NIH4 (more than six). Dummy variables are especially appropriate when using a model with qualitative data such as sex. Many of the hypothesized explanatory variables in the Carter landfill case are cardinal variables. However, one may use groupings or categories of a cardinal variable to define a qualitative variable (Johnston, 1984). The categories of the cardinal variable represent separate 0,1 dummies. To avoid having perfect multicollinearity, the last category for each explanatory variable was deleted from the regression equation.

Regression coefficients for the categories of an explanatory variable must be interpreted differently from regression coefficients of continuous variables. For instance, if NIH4 were the deleted category, the regression coefficient for NIH2 would measure the difference between average WTP for a three- to four-person household (NIH2) and average WTP for a household with more than six persons (NIH4), holding all other socioeconomic characteristics constant between the two households. Testing the significance of the coefficient of NIH2 is the same as testing the hypothesis that average WTP is equal for households in categories NIH2 and NIH4 (all other things constant). A joint F-statistic is used to test whether all categories of the NIH variable taken together significantly affect household WTP (Table 2).

These regression coefficients enable one to predict the external cost for a household, given its inclusion in a particular category for each variable. Interpretation of the these coefficients can be most effectively demonstrated by three examples. First, if the respondent fell into the deleted categories for all variables, the expected WTP value would be $1,911.20 (the intercept). Second, if the respondent fell into the NIH1 category and the deleted category for all other variables, expected WTP would be $2,059.93 (the intercept plus the coefficient for NIH1). Finally, suppose a respondent fell into the following categories: NIH1, AGE1, a male, INC1, EDU1, a renter, YIC1, used district water, MFL1, perceived no risk, then the estimate of his willingness to pay ($264.52) would be the intercept plus the corresponding regression coefficients.

The specific interpretation of the regression coefficients and their reliability as predictors of external costs is detailed below. It should be noted that the ceteris paribus assumption applies to the interpretation of all regression coefficients, but to avoid redundancy it is not explicitly stated below. Also, caution should be used when interpreting these WTP values. They do not indicate that Carter community residents would want to pay or that they should pay to avoid the siting of a landfill in their community. They can be interpreted as estimates of losses in welfare (costs) by residents if the landfill were located in their community.

Number in Household (NIH)

A joint F-statistic of 5.03 for NIH (Table 2) indicates that household size explains a portion of a household's WTP to avoid a landfill. Those households in the Carter community with three to four members were willing to pay more than households with more than six members. This is the expected result given that per capita income decreases as household size increases. The larger coefficient for NIH2 than for NIH1 probably reflects the increased concern respondents had as children were introduced into their household. This finding might be explained by the near proximity of the local high school and recreation area to the proposed landfill site. In fact, during the interviews, many respondents with children expressed this concern as their primary reason for opposing the BFI proposed site. The statistical nonsignificance of the coefficient for NIH3 suggests that, if children were present as accounted for by NIH2, additional children did not increase a household's WTP enough to offset decreases in WTP resulting from corresponding decreases in per capita income.

Age of Respondent(AGE)

The joint F-statistic for AGE as shown in Table 2 suggests that the respondent's age is significant in explaining household willingness to pay. The age variable was divided into five categories with the deleted category being those respondents over 65 years of age. Heads of household who were 45 years and under were willing to pay considerably less than those heads of household who were over 65 years of age. The coefficient for AGE4 (56-65 years of age) was significantly larger than the coefficients for the other categories. This may be due to the fact that those families typically had high school age children who were perceived to be at risk from the landfill.

Sex of Respondent(SEX)

From the results presented in Table 1, it appears that sex of the respondent was not a significant factor in determining household WTP.

Household Income(INC)

All coefficients for income were negative as expected, and they were all significant at the .01 level except INC4, which was not significant. The estimated coefficients' indicate that WTP was not appreciably different among households with incomes between zero and $29,999. Similarly, WTP was not significantly different for households with incomes of $30,000 or more. However, results indicate that WTP was about $1,000 less for households in the lower income group than for those in the higher income group. The joint F-statistic of 7.20 for INC indicates that income was highly significant in explaining household willingness to pay.

Education of Respondent (EDU)

The joint F-value of 10.8 for education is significant at the .01 level, suggesting that the level of education strongly influenced a respondent's WTP. As expected, all education variables had negative signs in relation to the deleted dummy variable of EDU4 (some graduate education). Although the regression coefficients indicate that college graduates were willing to pay relatively more than noncollege graduates, there was no difference in WTP among respondents with less than a college degree.

Homeownership (MOM)

Contrary to expectations, the regression coefficient for HOM was not significantly different from zero, suggesting that homeowners may not be willing to pay more than tenants to avoid having a landfill in the Carter community.

Years in Community (YPC)

The only dummy variable representing years of residence in the Carter community which was significant was YIC2 (one to five years). Its unexpected positive coefficient indicates that households which have resided in the community from one to five years would be willing to pay $156.92 more per year than those residents who had lived in the community for more than 15 years (the deleted dummy variable). This result may occur because newer residents are typically families with school age children who have moved into recently built subdivisions. Their higher WTP may reflect concern over the proposal to locate the landfill near community recreation facilities and the high school.

Drinking Water Source (DWS)

The regression coefficient for DWS was negative as expected. However, this regression coefficient is not statistically significant, so one cannot conclude'that DWS explains household willingness to pay in the Carter community.

Miles from Landfill (MFL)

The range for household distance from the proposed landfill was between zero and four miles. Two dummy variables (MFL2 and MFL3) were significant and, contrary to expectations, had negative coefficients, indicating that households within a two- to three-mile radius of the proposed landfill were willing to pay less than those located three to four miles away. Even though MFL1 had a positive coefficient as expected, its t-value indicates that a household located within one mile of the landfill would not be willing to pay significantly more than those residing between three and four miles from the proposed site. These regression results can possibly be explained by the fact that the newer subdivisions were located in the three- to four-mile range. Again, these residents were very concerned about their children's exposure to risks from the landfill. This finding suggests the possibility that distance from the proposed landfill site is less of a concern than perceived risks to school aged children.

Perception of Risk (POR)

Respondents were asked to rate their perceptions of risk, or level of concern over the proposed landfill, on a scale of one to five with one representing the greatest concern. Eighty-five percent of the respondents chose "one," the highest level of concern, and were willing to pay $226.16 more than the remaining 15 percent who chose "five," the lowest level of perceived risk from the landfill. The t-statistic of -5.62 in Table 1 indicates that perceived risk is a highly significant explanatory variable for WTP.

Conclusion

Results indicate that income, education, and a respondent's stated perception of risk are the three most important factors explaining a household's willingness to pay to avoid a landfill in the Carter community. Estimated coefficients for these variables are highly significant and large in magnitude relative to other variables included in the analysis. On the other hand, source of drinking water, homeownership, and sex of the respondent are not significant factors in explaining household WTP.

Four variables (NIH, AGE, YIC, and MFL) were also determined to be significant in explaining WTP. However, certain anomalies existed in their parameter estimates. In each case, these deviations from expectations might be attributed to the concern of respondents for the welfare of their children, given that the proposed landfill site is close to community recreation facilities and the high school. Including a direct measure of the influence of children by accounting for their numbers and ages might have allowed a more accurate estimate of the influence of children on household WTP. Therefore, the coefficients for NIH, AGE, YIC, and MFL should be interpreted cautiously.

Policy Implications

Regardless of what other options may be included in a comprehensive waste management plan, there is no doubt that a new landfill must eventually be sited in Knox County. Even with a massive recycling program, there would be wastes for which land disposal is necessary. What then does this study suggest about strategies for siting landfills?

If minimizing overall costs were the only objective, one might conclude that landfills should be sited in areas where the population has lower than average income and education levels. However, equity considerations would likely limit acknowledgement of such a strategy, at least explicitly or officially. In fact, proposals have been made by some legislators to require waste disposal facilities in all four quadrants of Knox County, which would require some distribution of the associated external costs among geographic areas and income classes.

Findings have important implications for the potential use of incentives in strategies to site landfills or other waste disposal facilities (Park, 1986). First, they suggest some idea of an appropriate or reasonable level of compensation to residents in the vicinity of a landfill, and how the level might vary depending on socioeconomic and other factors. Such a compensation strategy could be argued not only on equity grounds, but also on efficiency grounds, given the costs of protest, negotiation, and delay which could conceivably be avoided. The findings also provide insight into what types of mitigation techniques might or might not be effective in gaining acceptance of a landfill site. The lack of significance of the homeownership and drinking water source variables suggests that mitigation techniques designed to protect property values and drinking water supplies may not be effective. If community-wide attitude toward the landfill as a threat to community "sovereignty" or "reputation" is the key factor, gaining acceptance of a site by use of mitigation techniques may be quite difficult.

Table 1. Ordinary Least-Square Estimates of the Willingness to Pay Function to Avoid a Landfill in the Carter Community, Knox County, Tennessee

Explanatory Variable[a]	Category Definition	Regression Coefficient	t-Statistic 114 d.f.
Number in Household (NIH)			
NIH1	one to two	148.73	1.59
NIH2	three to four	193.19[d]	2.05
NIH3	five to six	29.21	0.27
NIH4[b]	greater than six		
Age of Respondent (AGE)			
AGE1	less than 35	-71.59	-1.33
AGE2	36 to 45	-143.12[e]	-2.82
AGE3	46 to 55	4.61	0.08
AGE4	56 to 65	87.14[c]	1.76
AGE5[b]	greater than 65		
Sex of Res~ondent(SEX)			
SEX1	female	16.54	0.47
SEX2[b]	male		
Household Income (INC)			
INC1	less than $10,000	-1,126.30"	-6.06
INC2	$10,000 to $19,999	-1,059.50"	-5.74
INC3	$20,000 to $29,999	-1,001.50[e]	-5.55
INC4	$30,000 to $49,999	-5.09	-0.01
INC5[b]	$50,000 and over		
Education of Res~ondent(EDU)			
EDU1	less than high school graduate	-796.03[e]	-4.90
EDU2	high school graduate	-733.39"	-4.63
EDU3	some college	-817.27"	-5.43
EDU4	college graduate	-432.80"	-2.91
EDU5[b]	some graduate school		
Homeownership (HOM)			
HOM1	homeowner	-97.74	-1.32
HOM2[b]	renter		
Years in Community (YIC)			
YIC1	less than one year	-38.45	-0.51
YIC2	one to five years	156.92"	3.47
YIC3	six to 15 years	-18.46	-0.52
YIC4[b]	15 years or more		

Table 1. (continued)

Explanatory Variable[a]	Category Definition	Regression Coefficient	t-Statistic 114 d.f.
Drinking Water Source (DWS)			
DWS1	district water	-27.88	-0.73
DWS2[b]	well or spring water		
Miles from Landfill (MFL)			
MFL1	adjacent to one	43.17	0.81
MFL2	one to two	-143.72[d]	-2.31
MFL3	two to three	-68.88[c]	-1.79
MFL4[b]	three or more		
Perception of Risk (POR)			
POR1	low risk	-226.16[e]	-5.61
POR2[b]	high risk		
Intercept		1,911.20[e]	12.27
$\bar{R}^2$		0.8751	
F-value		39.96	
Number of observations		140	

[a]All explanatory variables are 0,1 dummy variables. They take the value of one if the respondent falls in the corresponding category and zero otherwise.

[b]To avoid perfect collinearity, one dummy variable is deleted from the regression for each socioeconomic characteristic. The coefficients for the remaining dummy variable's estimate the difference in WTP from respondents in the deleted category, other things constant.

"Significant at the 10 percent level.

[d]Significant at the 5 percent level.

"Significant at the 1 percent level.

Table 2. Joint F-Tests for Explanatory Variable Groups in the Willingness to Pay Function of the Carter Community, Knox County, Tennessee

Variable Name	F-Test
NIH	5.03**
AGE	6.10**
EDU	10.78**
INC	7.20**
YIC	5.41**
MFL	3.44*

**Significant at the .01 level.

*Significant at the .05 level.

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