

A TEST OF PROXIMITY AS A PROXY FOR ENVIRONMENTAL EXPOSURE IN HEDONIC MODELS†

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ABSTRACT

Housing location affords individuals proximity to site-specific amenities (disamenities) such as parks, wetlands, airports, nuclear facilities, landfills, brownfields, and other contaminated sites. A deep vein of economic literature examines the economic effects of environmental conditions tied to location using the hedonic method. Distance to the geographic feature of interest is commonly used as a proxy for exposure to the condition. However, there exists little evidence regarding the degree to which proximity-based measures of net benefits reflect the value of removing the condition and thus eliminating exposure. However, it is this latter net benefit estimate that is of direct interest to policy makers. This paper reports the results of a conjoint choice experiment conducted in association with a hedonic property value study to test the role of proximity to a contaminated site as a proxy for exposure to the site, and to estimate the benefits of site cleanup.

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INTRODUCTION

A deep vein of the environmental economics literature uses hedonic methods to analyze the effects of geographically-distributed environmental conditions on property markets. The mining of this vein began 40 years ago with the publication of Ronald G. Ridker and John A. Henning's (1967) pioneering study of air pollution's effects on residential property values. In the ensuing years, following the formalization of the hedonic method by Rosen (1974), real estate-based applications have been used to assess the market effects of a wide variety of site-specific amenities/disamenities including parks, wetlands, airports, brownfields, nuclear facilities, landfills, sports stadiums, and confined animal facilities.

This paper addresses a specific issue in hedonic property value estimation – the use of distance as a proxy for environmental exposure. With localized environmental anomalies, other locations are affected by their spatial relation to the place where the anomaly occurs. The linkage between cause and effect could be through “exposure” to the environmental condition, such as ease of access to a park or unmeasured dispersion of toxicants from a contaminated site. It could also arise from stigmatization (e.g., Dale *et al.*, 1999; McCluskey and Rausser, 2003; Patunru, Braden, and Chattopadhyay, forthcoming). Whatever the linkage, proximity to the environmental intrusion is hypothesized to correlate with impact — the impact on neighboring properties exceeding that for more distant properties. The distance variable carries all of the weight of the localized environmental condition.

Policy analysis, on the other hand, is typically concerned with estimating the net benefits of improving the environmental condition of an offending site(s). To directly determine the

market effects of a change in environmental quality at a site requires information on market transactions before and after the change in environmental quality. This information is rarely available since most policy analyses are prospective in nature. Thus, most studies rely on estimates of the value of increasing/decreasing proximity to a site to estimate the benefits of changing the environmental condition of the site. For proximity to accurately measure the value of environmental quality changes, a number of assumptions must be invoked that relate to distance to a site, environmental quality, and the resultant exposure for nearby properties.

In this paper, we report the results of a hedonic analysis of residential property sales that is directly linked at the household level to a choice experiment. The application examines the effect of contaminated water bodies on the residential property market. The choice experiment varies prices, the location of homes relative to the contamination, and the environmental condition. Comparisons are made between the hedonic gradients based on proximity to a contaminated site and willingness to pay estimates that disaggregate the effects of environmental quality at a site from proximity to the site. These data allow for direct tests of assumptions underlying hedonic models in this context – that the price differential due to proximity provides an accurate measure of the economic effect of changes in a location-based environmental condition.

In the following sections, we first offer a theoretical statement regarding the linkages between distance to a contaminated site, environmental quality, and the resultant exposure for nearby properties. We also present the specific propositions to be tested. Next, we describe the case study and data. We then present the estimation results and conclude with a discussion of the findings in relation to our hypotheses.

CONCEPTUAL FRAMEWORK

Hedonic Model

The hedonic context for measuring environmental cleanup values begins with the assumption that the purchase of real property reveals information about household values for site-specific amenities or disamenities. In the case of interest here, the disamenity is the potential health risks from exposure to hazardous substances that proximity of a residence to a contaminated site(s) conveys. Exposure and resulting health risks, X , are presumed to be a function of both the distance of the home to the site, D , and the environmental condition of the contaminated site, E , or $X = f(D, E)$. For ease of exposition, X is defined in such a way that positive increments in X would lead to increases in a homeowner's utility, i.e., X represents reductions in exposure. To be consistent with the definition of X , D represents distance from the contaminated site ($\partial X/\partial D > 0$), and E is an index of contamination for which increases indicate less environmental contamination and, hence, exposure ($\partial X/\partial E > 0$).

Focusing initially on consumers of housing, let the utility of the i^{th} individual be given by:

$$U(\underline{Z}, X, R, \alpha^i), \quad (1)$$

where \underline{Z} is a vector of housing, neighborhood, and locational characteristics, X is environmental exposure at the home chosen, R is the numeraire good, and α^i are the relevant socioeconomic characteristics of individual i . The consumer maximizes utility subject to the budget constraint: $y = P(\underline{Z}, X) + R$, where $P(\underline{Z}, X)$ is the exogenous price schedule for housing. The consumer's optimal budget allocation is characterized by equality of the marginal rate of substitution between home attributes and the numeraire, with the price ratio:

$$\frac{U_X}{U_R} = P_X, \quad (2)$$

where $U_X = \partial U(\bullet)/\partial X$, $U_R = \partial U(\bullet)/\partial R$, and $P_X = \partial P(\underline{Z}, X)/\partial X$.

Following Rosen (1974), it is convenient to represent the consumer's problem as one of formulating an optimal bid for each house. The bid function for person i may be defined as:

$$U(y - \theta, \underline{Z}, X) \equiv U^0. \quad (3)$$

The indicator of an individual's socioeconomic characteristics, α , is omitted for brevity. Note that it is exposure at the housing site which enters utility, and not proximity to the contaminated site (D) or the environmental quality of the contaminated site (E). This assumes that there are no external effects of the contaminated site other than its conveyance of health risk to the housing unit. The plausibility of this assumption would depend on the land-use of the environmentally contaminated site. Later, we discuss how relaxing this assumption impacts our analysis.

Solving equation (3) for the bid function makes clear that bids are functions of both the utility level and income of the consumer:

$$\theta = \theta(\underline{Z}, X, U^0, y). \quad (4)$$

Substituting $\theta(\bullet)$ into (3) and optimizing with respect to changes in X implies the following condition for placing an optimal bid:

$$\theta_X = \frac{U_X}{U_R}, \quad (5)$$

where $\theta_X = \partial \theta(\bullet)/\partial X$ and all other partial derivatives are as defined earlier. A similar condition can be defined for the marginal bid for any housing characteristics, θ_Z . The bid function has the following properties: $\theta_X > 0$, $\theta_{XX} < 0$, $\theta_{U^0} < 0$, and $\theta_y = 1$. Furthermore, from equation (2), it is clear that a consumer will choose levels of housing characteristics such that $\theta_X = P_X$.

Figure 1 presents two bid function contours for a specific individual, where $U^1 < U^0$. The consumer faces the exogenous hedonic price function, $P(\underline{Z}, X)$, and, given his preferences and income, chooses a home at price P_0 with a level of environmental exposure of X_0 . The price function in Figure 1 presumes the existence of \bar{X} , a level of exposure reduction beyond which there is no further incremental value in home prices. In other words, there is a level of exposure so small that further reductions do not add to housing value.

The value of an exogenous, marginal increase in X is given by θ_X or P_X . However, from a policy perspective, we are typically interested in discrete changes in environmental exposures. As described in Taylor (2002), under some conditions, the value or net benefit (NB) of a discrete change in the level of exposure from X_0 to X_1 is given by $P_1 - P_0$, and, under a variety of conditions, this price difference is an upper-bound on net benefits.¹

The preceding discussion focuses on site-specific “exposure.” This is the characteristic that is valued by consumers and conveyed to them via their choice of housing. However, from a policy perspective, we often wish to know the value of *cleanup* of a contaminated site. If we allow complete cleanup of a site to be represented by \bar{E} , then we wish to measure the net benefit of a change from the initial condition, E_0 , to this upper-bound on quality. To link cleanup to changes in exposure, we only need $f(D, E)$ to be continuous and twice-differentiable in E and, for any D_0 , there must exist an E such that $\bar{X} = f(D_0, \bar{E})$. For a consumer located at D_0 distance from the contaminated site, it is then the case that:

¹ The sum $P_1 - P_0$ represents the net benefit of a discrete change in X in a localized context when transactions costs associated with moving are assumed to be zero. If transactions costs are positive, but are not so great as to prohibit moving ($P_1 - P_0 - TC$, where TC is transactions costs) is an exact measure of net benefits. If households cannot relocate because transactions costs are prohibitively high (or there are no available houses identical to the one they owned prior to the change in the amenity, then $(P_1 - P_0 - TC)$ is an upper bound on net benefits. See Taylor (2002) for a detailed discussion of how the hedonic price function may be used to measure net benefits of an amenity change.

$$U(D_0, \bar{E}, \underline{Z}, R) = U(\bar{X}, \underline{Z}, R).^2 \quad (6)$$

And, given the following condition at the consumer's observed housing choice where $X=X_0$:

$$U(D_0, E_0, \underline{Z}, R) = U(X_0, \underline{Z}, R), \quad (7)$$

then, equations (4) and (6) also imply:

$$\theta(D_0, \bar{E}, \underline{Z}, U, y) = \theta(\bar{X}, \underline{Z}, U, y). \quad (8)$$

In this case, the value of site cleanup as evaluated by a market hedonic price function defined over exposure at each house is given by $P_{\bar{x}} - P_0$, where $P_{\bar{x}}$ is the price of housing at the upper-bound of exposure reduction. The result is illustrated in Figure 1, where $P_{\bar{x}}$ and P_0 indicate the house price evaluated at \bar{X} and X_0 levels of exposure, respectively.

Empirical applications of the hedonic framework to real estate markets rarely include measures of house-level environmental exposure (X) and rarely have the information available that is necessary to evaluate the impacts of site cleanup, ΔE .³ Evaluating changes in environmental quality requires information pre- and post-cleanup, whereas most studies are conducted only *ex-ante* as a part of prospective benefit/cost analyses.⁴ As a result, most hedonic studies measure net benefits of cleanup relying on the following thought experiment. First, it is assumed there exists some distance from a contaminated site for which there is no exposure associated with that location. In other words, for any E_0 there exists a distance, \bar{D} , such that $\bar{X} = f(\bar{D}, E_0)$. This assumption is certainly plausible for most exposures that result from a

² This relationship implies the absence of non-use values in the utility function. More generally, a consumer may have non-use values for cleanup, but we would not expect these to be present in the sub-utility function associated with housing choice.

³ The study by Gayer, Hamilton, and Viscusi (2000) represents an exception to this generalization. They differentiated general distance to a contaminated site from distance to a groundwater plume emanating from the site, calling the former a measure of stigmatization and the latter a measure of actual risk.

⁴ Exceptions include Dale *et al.* (1999), McCluskey and Rausser (2003), and Zegarac and Muir (1998), who evaluated property markets before and after environmental cleanups.

contaminated site. The value of site cleanup is then assumed to be equivalent to the change in value of a property that would occur if that home was located at \bar{D} instead of D_0 . More formally, for any E_0 , we assume there exists a \bar{D} such that:

$$U(\bar{D}, E_0, \underline{Z}, R) = U(\bar{X}, \underline{Z}, R), \quad (9)$$

and given the following condition at the consumer's chosen house:

$$U(D_0, E_0, \underline{Z}, R) = U(X_0, \underline{Z}, R), \quad (10)$$

equation (9) implies:

$$\theta(\bar{D}, E_0, \underline{Z}, U, y) = \theta(\bar{X}, \underline{Z}, U, y). \quad (11)$$

It is important to note that equation (9) and (11) only hold if distance to the contaminated site has no external effects (positive or negative) other than its contribution to exposure.

If equations (8) and (11) hold, then the value of site cleanup can be evaluated by a market hedonic price function defined over distance of each house to an environmentally contaminated site. The net benefits associated with cleanup are computed by $P_{\bar{D}} - P_0$, where $P_{\bar{D}}$ is the price of housing at distance \bar{D} . In other words, under the conditions stated above:

$$P_{\bar{D}} - P_0 = P_{\bar{E}} - P_0 \quad (12)$$

While the preceding relationships hold theoretically under the conditions stated, data limitations or market/site conditions may violate (12). Incomplete specification of \underline{Z} can result in inequality of (8) if the omitted variables are correlated with distance. For instance, unobserved locally undesirable land-uses that are spatially correlated with the site(s) of interest would mean that distance provides a biased estimate of the value of exposure. Or, spatially heterogeneous buffers between the contaminated site and housing areas could result in

directional-distance being the correct specification (Cameron, 2006). Spatial lag or spatially-corrected error models will not alleviate these issues.

For most empirical applications, testing the degree to which net benefit estimates based on proximity to a specific site accurately reflect the net benefit of environmental change at the site is not possible within the context of just a hedonic property value model. This study employs data from a secondary source, a conjoint choice survey of recent homebuyers, to explore the degree to which net benefits based on distance correspond to those based on the underlying environmental condition. Parallel estimates of cleanup benefits are estimated using traditional hedonic property value model and a choice model. The context for the choice survey is presented next, followed by a discussion of the hypotheses to be tested.

Conjoint Model

An alternative approach for analyzing house purchase decisions employs a discrete choice framework, which permits direct estimation of the utility function parameters. Cropper *et al.* (1993) introduced random utility models (RUM) to real estate market analysis using conventional market data. Earnhart (2000, 2002), Braden *et al.* (2004), and Chattopadhyay *et al.* (2005) adapted the RUM model for use with survey data. However, none of these studies challenge the assumption that distance is an unbiased proxy for the external impacts of a site-based environmental condition.

Following Hanemann (1984), the utility that the i^{th} individual receives from purchasing the j^{th} home is assumed to be composed of a deterministic portion and a random error, ε , that reflects the unobservable (to the researcher) components of utility, or:

$$V_{ij} = V(y_i - P_j(\underline{Z}_j, \underline{X}_j), \underline{Z}_j, \underline{X}_j, \alpha_i) + \varepsilon_{ij}, \quad (13)$$

where $V(\bullet)$ represents the conditional indirect utility function and all other variables are as described above. Note, the above formulation focuses on choices as a function of exposure at a housing location, X . Substituting $f(D, E)$ for X in the above yields:

$$V_{ij} = V(y_i - P_j(\underline{Z}_j, D_j, E), \underline{Z}_j, D_j, E, \alpha_i) + \varepsilon_{ij}. \quad (14)$$

Assuming the random component of utility is identically and independently distributed type-I extreme value, the probability that individual i chooses house j , from the set of J homes is:

$$\pi_i(j) = P(V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik}; \forall j, k \in J), \quad (15)$$

which can be translated into the conditional logit model:⁵

$$\pi_i(j) = \frac{\exp(\lambda V_{ij})}{\sum_{k \in J} \exp(\lambda V_{ik})}. \quad (16)$$

The value of a marginal change in D is given by:

$$\frac{V_D}{V_y} \text{ and } \frac{V_E}{V_y} \quad (17)$$

where $V_D = \partial V / \partial D$, $V_E = \partial V / \partial E$, and $V_y = \partial V / \partial y$. And, in the absence of an income effect, the expected compensating variation (CV) for a discrete change in D or E is calculated using the following log-sum formula (see Bockstael *et al.*, 1991):

$$E(CV) = \frac{1}{\gamma} \left[\ln \sum_{i \in J} \exp(V^1_i) - \ln \sum_{i \in J} \exp(V^0_i) \right], \quad (18)$$

where γ is the marginal utility of income, and the superscripts 0 and 1 indicate the observed utility in the base and new situations, respectively.

In the context of our choice survey, individuals are presented with a choice of two homes: their current home, and a home that is identical to their current home in all ways except for its

⁵ Without loss of generality, we assume the location parameter is one (Louviere *et al.*, 2000).

size, price, proximity to a contaminated site, and the condition of that site. This structure allows us to identify the household's willingness to make hypothetical trade-offs between house price, environmental conditions at the contaminated site, E, and proximity to the site, D.

Hypotheses

As described above, the choice survey has a structure that allows estimation of the value of proximity (or distance) holding environmental quality constant, and also allows estimation of the value of environmental cleanup holding proximity constant. Thus, we can employ the conjoint data to test the following hypothesis:

$$H_{01}: \quad NB^{CJ} \{(\bar{D} - D_0), E_0, \underline{Z}\} = NB^{CJ} \{D_0, (\bar{E} - E_0), \underline{Z}\}, \quad (19)$$

where NB^{CJ} is the net benefit (WTP) measure for ΔD or ΔE calculated with the conjoint survey results. Failure to reject the presumed equality provides evidence that the proximity discount is, at least in our application, a reasonable proxy for cleanup at contaminated sites.

While we would like to test a hypothesis similar to (19) using only hedonic data, as discussed above, that is not possible. Instead, we look to an ancillary test that examines the relationship between the net-benefit estimates arising from the two analytical methods. We explore whether, with distance held constant, the distance-based RUM estimates of welfare change approximates the hedonic estimate for elimination of the proximity discount. The hypothesis is formally stated as follows:

$$H_{02}: \quad NB^{CJ} \{(\bar{D} - D_0), E_0, \underline{Z}\} = NB^H \{(\bar{D} - D_0), E_0, \underline{Z}\}, \quad (20)$$

where NB^H represents the net benefit estimate arising from a hedonic property value model based on changes in distance to a contaminated site, and all else is defined earlier. Support for H_{02} implies that the different analytical methods are estimating the same phenomenon.

For completeness, we also explore the relationship between the RUM estimates of welfare change associated with AOC cleanup and the hedonic estimate for elimination of the proximity discount. The hypothesis is formally stated as follows:

$$H_{03}: \quad NB^{CJ} \{D_0, (\bar{E} - E_0), \underline{Z}\} = NB^H \{(\bar{D} - D_0), E_0, \underline{Z}\}. \quad (21)$$

Support for (19), (20), and (21) together would be quite powerful, providing evidence of convergence validity for stated and revealed preference estimates, as well as support of the maintained assumptions in hedonic analyses that are routinely taken for granted, but rarely tested. If, on the other hand, we reject any (or all) of the above hypotheses, it may suggest a lack of convergent validity, or a failure of the maintained assumptions in the hedonic model.

However, rejection may also occur due to limitations in the data and estimation methods, which we will attempt to explore as appropriate.

In summary, we first examine whether the conjoint choice experiment results are consistent with the principle that environmental exposure is fully captured in proximity discounts. Next, we compare the net benefit estimates from the choice experiment and the hedonic model to discover whether they produce consistent results. Failure to find equality between the two measures could arise from a failure of any one of a number of the underlying maintained assumptions. To the extent that we find a difference between NB^{CJ} and NB^H , we will explore source of the possible deviation.

APPLICATION⁶

Study Site

⁶ A complete account of the case study is available in Braden *et al.* (2006)

The 1987 Amendments to the Great Lakes Water Quality Agreement between the U.S. and Canada designated 43 sites in the Laurentian Great Lakes, and their tributaries, as Areas of Concern (AOC). A common feature of these areas is the presence of toxic chemicals – notably polychlorinated biphenyls (PCBs) – known to cause cancer and neurological/developmental defects in humans and to bioaccumulate in aquatic foodwebs. The AOCs are essentially aquatic Superfund sites.⁷ During the ensuing 20 years, only two Canadian sites and one U.S. site have been delisted. The remaining remedial activities on the U.S. side are expected to cost from \$1.5 billion to \$4.5 billion (Great Lakes Regional Collaboration, 2005). There is considerable interest in discerning whether further expenditures on cleanup will produce benefits consonant with the costs. A 35% non-federal match is required to secure federal funds, so the question of who benefits can also help identify potential sources of non-federal funding.

The Buffalo River, NY, AOC consists of a commercial harbor and a 6.2 mile segment of the river eastward from its terminus at the eastern end of Lake Erie.⁸ A schematic map of the site appears in Figure 2. The eastern portion of the AOC includes a small section of a tributary. The AOC is flanked by a large industrial complex. The industrial sector is in decline and brownfield sites abound. Nevertheless, there are also private homes nearby – the 2000 Census counted 52,628 single-family homes within five miles. Our focus is on the effect of the AOC, and the potential benefits of remediation, on the market value of these private homes.

Real Estate Data

All data in our analysis relate to single family, owner-occupied home sales during the period January 1, 2002 to December 31, 2004 that occurred within five linear miles of any point

⁷ In the U.S., Superfund sites are the most toxic sites identified and eligible for remediation under provisions of the Comprehensive Environmental Response, Cleanup, and Liability Act of 1980. Many Great Lakes AOCs are closely linked to onshore Superfund sites.

⁸ A more detailed description is available at: www.epa.gov/glnpo/aoc/buffalo.html.

along the Buffalo River AOC.⁹ Figure 2 contains a schematic map of the study area and of the properties sold during the study period. These particular properties were chosen because they reflect recent conditions of the property markets in the target areas. The buyers presumably represent a random cross-section of housing and owner types. They would be likely to possess current knowledge about, and impressions of, the AOC. The study area encompasses most of the City of Buffalo, all of Lackawanna, and portions of Cheektowaga, Hamburg, and West Seneca. Two smaller jurisdictions, Blasdell and Sloan, also lie within the study area, but the data for the two small jurisdictions are sparse so we merge them with the data for the assessing jurisdictions, Cheektowaga and Hamburg, respectively. Table 1 provides selected census data for households in the vicinity of the Buffalo River AOC.

Several primary databases are combined to characterize homes sales in our study jurisdictions. The first data set came from local tax assessors and contains sales prices and dates and characteristics of the housing, including: a) lot size; b) square footage of improvements; c) age of primary structure; and d) miscellaneous housing characteristics. We normalized all prices to 2004 dollars using the house price index for the Buffalo-Niagara metropolitan statistical area provided by the U.S. Office of Federal Housing Enterprise Oversight. The first section of Table 2 reports names and definitions for each of the variables contained in the above categories and the first section of Table 3 reports summary statistics.

The second primary database describes spatial features of properties that sold during our study period. Of primary interest are: a) proximity of the house to the AOC; b) proximity of the house to other important location-specific amenities or disamenities such as the shoreline of Lake Erie, other rivers, railways, highway intersections, central business districts, airports, and

⁹ We also collected data for multi-family residences, but we did not administer the survey to multi-family occupants so those data are not included in the current analysis.

local parks; and c) census tract, census block, and school district in which the house is located. Once again, location-related variable name and descriptions appear in tables 2 and 3.

The second section of Table 3 reports the distribution of sample properties across the jurisdictions in the study area. Forty-two percent of the properties are located in the City of Buffalo (of those, 70% are located north of the AOC). Cheektowaga and West Seneca contain another 23% and 25% of the parcels in our sample, respectively. Lackawanna and Hamburg/Blasdell contain a modest number of properties that sold during our study period; 7.5% and 2%, respectively. Overall, 47% of the sample is located north of the Buffalo River.

Using a GIS map of the Buffalo area,¹⁰ we created variables that reflect each parcel's location relative to the features of interest. These variables are described and summarized in the last sections of tables 2 and 3. The 3.8 mile mean distance to the Buffalo CBD reflects a relative sparseness of sales in inner-city Buffalo. The mean distance between homes and streams other than the AOC is 1.6 miles while the mean distance to the AOC is approximately three miles. The latter distance does not vary much between the north and south sectors. Although not reported in Table 3, 12% of homes north of the AOC and 16% of the homes located to its south are within 1.5 miles of the AOC. The mean distance to the Lake Erie shoreline is 3.7 miles. Also of particular note is the proximity to rail corridors (mean=0.66 miles) and highway corridors (mean=0.77 miles; 0.95 miles to an interchange). These features figure prominently in the study area. The regional airport lies outside our study area, so the mean distance to properties in the sample is almost six miles.

Absent from Table 3 are 118 dummy variables included in the analysis, each one representing a census tract in which a property is located. Census tracts are designed to be

¹⁰ Provided by John Whitney of the East Aurora, NY office, NRCS/USDA.

relatively homogeneous with respect to population characteristics, economic status, and living conditions.¹¹ By including census tract identifiers, our analysis indirectly captures infrastructure and demographic factors that influence home choices. These factors are thereby removed from the proximity variables, which then are free to reflect preferences for the object of the distance calculations (e.g., highways, parks, or the AOC) rather than conditions at the residence itself.

Survey Data

Based on the home sales data, we randomly chose 850 properties to receive a survey.¹² In order to achieve statistical significance at the taxing jurisdiction level, the sample was stratified to over-represent jurisdictions with fewer home sales. The survey was designed to complement the real estate market data. Three types of data were collected: 1) Information to verify current home characteristics and to assess respondent attitudes toward housing and the AOC; 2) responses to conjoint choice questions; and 3) household demographic information and reactions to the survey.

The choice questions asked respondents to imagine that additional homes had been on the market during their recent home-buying experience. Hypothetical homes were then offered to them, one by one. Respondents were asked whether, at the time of purchase, they would have preferred the hypothetical home to the home they actually bought. A representative choice question appears in Figure 3.

In order to focus respondents' attention on variables of interest and to make the choices as concrete as possible, the hypothetical homes were described as being identical to their current

¹¹ See <http://www.census.gov/main/www/cen2000.html>.

¹² The survey instruments were developed with assistance from the University of Illinois Survey Research Laboratory (SRL) and in cooperation with the Great Lakes Program, University at Buffalo.¹² Early versions were assessed by focus groups held at a public library branch in West Seneca, NY, in early 2005. Advanced versions were pretested in Spring 2005. For the final survey, respondents could either mail back a completed questionnaire or complete an equivalent instrument using the Zoomerang.com commercial survey website. Approximately nine percent of the responses were received online.

home except for selected attributes. Those attributes were chosen to focus on trade-offs between private aspects of homes and the surrounding neighborhood, particularly the AOC. In designing conjoint choice questions, the literature supports a balance between detail sufficient to make choices realistic and plausible, and simplicity that allows the choices to be readily understood and responded to (e.g., Louviere, Hensher, and Swait, 2000). Accordingly, we limited the choice questions to four attributes. All of the attributes were described in relation to the home currently owned or the neighborhood condition that existed at the time of purchase. The private home characteristic we used is the size of the residence. In virtually all hedonic studies of housing, size is highly significant in influencing price. The two other attributes were proximity of the house to the Buffalo River and the environmental condition of the river. For proximity, we asked respondents to imagine the river being closer to their home without changing other features of the neighborhood. The environmental condition was varied qualitatively, with toxic pollution increasing, decreasing, staying the same, or being eliminated.

Each of the three attributes, and the price of the hypothetical house, was allowed to take on four levels. The levels are summarized in Table 4. A choice alternative consisted of one level for each attribute. With four attributes and four levels per attribute, there are 4^4 or 256 possible combinations. Rather than examining all possible combinations, we used a fractional factorial design that varies the attributes in a manner that assures orthogonality – that is, that the design itself does not introduce correlation between variables. The orthogonal design extends to two-way interactions between the choice variables (Montgomery, 2000). Sixty-four choice alternatives resulted from the design.

For size and price, the levels are proportioned to the comparable value for the home currently owned. This has the advantage of scaling the alternatives to be realistic for each

respondent while also transforming discrete “level” variables into continuous variables. For proximity, out of concern for the possibility that residents would not know the distance of their current home to the river, we used precise nominal deviations from current distance.¹³ For the environmental variable, there is no obvious way to reduce it to a univariate index.

We randomly assigned the 64 alternatives into eight groups of eight alternatives. Each group was included in a version of the survey instrument. The versions differed only in the attribute combinations used in the conjoint choice questions. Table 5 summarizes the survey distribution and responses. Appendix tables A.1 to A.6 provide further insights into the survey responses and tests of their reasonableness and representativeness.

ESTIMATION RESULTS

Hedonic

The discussion and presentation of the hedonic model results focus on the relationship between sales price and proximity to the AOC. We examined several commonly-used functional forms for the hedonic price function that are consistent with our expectations regarding the general relationship between price and distance to the AOC (Braden *et al.*, 2006). Here, we report results for the following linear-log model:

$$saleprice = \alpha + \beta_1 \ln(AOC) + XB + \varepsilon, \quad \text{and } \beta > 0 \quad (22)$$

¹³ To deal with the possibility that a current home is already quite close to the river, the closer distances were qualified by the phrase “or next to the river if your current home is closer than...”

where *saleprice* and *AOC* are as defined in Table 2. All other housing attributes and location characteristics are subsumed in the vector *X* and are listed in Table 2.¹⁴ The error term is given by ε . The parameters α , β_1 , and vector *B* are to be estimated.¹⁵

The estimation results are reported in Table 6. Before discussing the results for the *AOC*, we briefly discuss the results for other housing attributes. The coefficient estimates for the variables describing the housing characteristics are of the expected sign and generally are statistically significant at the 5% level or better. We allow a cubic relationship between age of a home and sales price to reflect that although age typically reduces sales price, as homes become “quite old” (i.e., become “historic”), they often increase in value. The coefficient estimate for the variable indicating the number of bedrooms is negative and significant at the 10% level. This may seem counterintuitive, but we also control for square footage of the home, so this coefficient estimate reflects not only the value of adding a bedroom, but also of having smaller bedrooms (in order to keep the overall square footage the same).

Two types of location-related variables (other than *AOC*) are included in the model. The first type includes dummy variables that indicate the jurisdiction, census tract, and whether or not the property was located north of the *AOC* (see “Locational Dummy Variables” in Table 6). The jurisdiction not included in the model is the portion of the City of Buffalo to the north of the *AOC*.¹⁶ The division of the City of Buffalo into two sectors is motivated by potentially important differences between the two areas. In particular, just north of the *AOC* is a substantial

¹⁴ Other functional forms explored include those which modify equation (22) by taking the natural log of the dependent variable and/or taking the inverse of distance to the *AOC* (raised to a variety of powers) instead of taking the natural log. Results for these models are consistent with the model reported in (22). We report comparison results for the $\ln(\text{saleprice})$ models or inverse models in footnotes when appropriate.

¹⁵ We correct for an unknown form of heteroskedasticity using a Huber/White/sandwich estimator for the variance/covariance matrix.

¹⁶ The dummy variable for Hamburg is excluded from the model because of collinearity between it and other location variables included in the model.

railway network, interstate highway, and an industrial zone. Residential density in this area is relatively sparse. The impacts of the AOC on homes in this area and further north may be different from those to the south, where there are fewer potentially confounding non-residential land uses separating residential areas and the AOC.

As indicated in Table 6, after controlling for home features and other location characteristics of the property, homes in the City of Buffalo south of the AOC, as well as homes in West Seneca and Lackawanna, sell for significantly less than homes in the City of Buffalo north of the AOC. The coefficient estimate for Cheektowaga is also negative but not significantly different from zero. The coefficient estimate for the dummy variable (*north*) indicating a home is located north of the Buffalo River is not significantly different from zero.

The second type of location-related variables included in the model captures distances between individual properties and geographic features of potential importance to homeowners (see Table 5, “Proximity Variables”). In our regression models, seven of these characteristics were interacted with a dummy variable indicating whether or not the property was north of the Buffalo River. Results are generally consistent with our expectations based on local market conditions.¹⁷ Of particular note is the result that proximity to a hazardous waste site, other than the AOC, significantly reduces property values in both the northern and southern sectors.¹⁸ Also, proximity to an uncontaminated stream does not significantly affect property values in either the northern or southern part of the study area, and home values actually increase with distance from the shoreline of Lake Erie, although this effect is insignificant for properties south

¹⁷ All housing, location, and proximity variables are consistent in models in which proximity variables are entered as inverse distance instead of $\ln(\text{distance})$. The manner in which continuous housing characteristic variables are entered do not vary across models.

¹⁸ Significance of proximity to a HWS for properties to the south of the AOC is determined by an F-test of the null hypothesis that the sum of two coefficients are equal to zero (i.e., $H_0: \beta_{Inhws} + \beta_{Inhws*north} = 0$).

of the AOC. The majority of the shoreline is characterized by industrial or highway frontage and is not readily accessible. Under these circumstances, the negative impact of proximity to the shoreline is not surprising.

In general, in the southern sector, fewer location characteristics are significant predictors of property values. Proximity to a park, rail lines, uncontaminated streams, the airport, and the shoreline do not significantly impact property values. These findings are realistic for the geography of the area. For instance, to the south there are few rail lines in close proximity to households, which contrasts with the north. Also, the airport is located closer to the northern sector.

Turning to the variable of main interest, proximity to the AOC, we see in Table 6 that it has a statistically significant, negative impact on single-family homes located south of the Buffalo River, and a small and statistically insignificant impact on housing prices to the north of the AOC. The active rail lines, interstate highway, and industrial zones located just north of the Buffalo River appear to act as a buffer between the residential real estate market to the north and the AOC, and may overwhelm the influence of the AOC.¹⁹

The marginal impact of the AOC on homes to the south diminishes rapidly. For purposes of reporting, the distance variables are converted to 1/10th mile increments. The coefficient estimate for proximity to the AOC indicates that, for homes adjacent to the river (1/10th mile), values would increase approximately 8% of the mean house price per additional 1/10th mile of

¹⁹ These results are robust to changes in the specification of the AOC variable (i.e., using the inverse of proximity to the AOC). To explore this conjecture further, we modify our definition of the “north” in our models. Recall, the area to the north of the AOC is characterized by crisscrossing rail lines, a heavily-industrial area, and there is a major highway corridor that lies between the AOC and most of our sample. However, several homes are located within a mile of the AOC to the north, but to the south of the highway and the major rail corridor in that area. We re-estimated our models assuming that the homes that lie between the AOC on the north-side and the highway/railroad corridor may be affected by the AOC like homes to the south of the AOC. Results remain unchanged. The magnitude of the coefficient estimate for the “south” is only marginally changed, and the impact on homes to the north continues to be insignificant.

distance²⁰. But, just one mile from the river, the added value per additional 1/10th mile of distance is less than 1%. The gradient of marginal changes in home value is shown in Figure 4.

For comparison with the conjoint survey, we wish to estimate the realized capital loss associated with each property's proximity to the river. In terms of our earlier discussion, we estimate $(P_{\bar{D}} - P_{D_0})$. Based on equation (22), the reduction in property value for house j , located at a distance of D_0 , is given by:

$$(P_{\bar{D}} - P_{D_0}) = \text{saleprice} \Big|_{\bar{D}} - \text{saleprice} \Big|_{D_0} = \beta_1 \left[\ln(\bar{D}) - \ln(D_0) \right], \quad (23)$$

where $\text{saleprice} \Big|_{D_0}$ is the predicted price of house j at its actual distance from the AOC, and $\text{saleprice} \Big|_{\bar{D}}$ is the predicted price of house j at the hypothetical "boundary" distance from the AOC. The boundary distance assumed is that for our study area: five miles from the AOC.

For a property located at the approximate mean distance from the AOC of 2.5 miles, the per-household estimated discount is \$4,692, or approximately 7% of a mean property value of \$84,619. For properties located closer to the AOC initially, say at 0.5 miles, the estimated per-household price discount is more substantial: \$15,588 or 23% of the mean property value of \$84,619. Additional computations for net benefits at different assumed initial conditions are presented in subsequent sections in the course of comparing the hedonic and conjoint results.

The calculation of the price discount only requires information on proximity of a property to the AOC. Thus, we calculate aggregate proximity discounts using all homes in the study area,

²⁰ A mean sale price of \$84,619 is used. This is the mean of the conjoint response sample, to which we later compare hedonic estimates. The mean sale price of homes to the south of the AOC in the hedonic sample is \$66,000.

not just those which sold during 2002-2004.²¹ We calculate the price discount for each home in the study area, then sum these individual amounts. The estimated total capital losses south of the AOC, within five miles, are \$118 million. These losses represent approximately 5.5% (\$5,142 per home, on average) of total assessed value of the properties within five miles, south of the AOC. Note that assessed value is likely to underestimate the actual market value of the property.

Conjoint Choice

First, we estimate a relationship between the attributes included in the choice questions and the utility derived from a home. Second, based on the utility model, we derive a marginal utility of income and compute compensating variation measures of expected willingness to pay for changes in the environmental condition of the AOC. We focus initially on the effect of distance (*DIST*) to the AOC on WTP.

The estimation employs the conditional logit model. In addition to the choice variables, the specification includes an alternative specific constant ($ASC=1$ for the current home; 0 for the alternative) and socio-economic characteristics that might influence choice. The characteristics that are introduced via interactions with the attributes of housing are the number of individuals in the household (*FAMILY*) and annual household income (within ranges; *Y*). A dummy variable distinguishing respondents located north of the river from those residing to its south was included in initial models, found to be consistently not a significant predictor of choice, and is omitted. Unlike the hedonic results, the survey provided no evidence of north/south separation, a matter we revisit when presenting our results.

²¹ The maintained hypothesis is that the homes which have sold during our study period are effectively a random sample of homes in the entire study area. This is reasonable if proximity to the AOC does not systematically affect which types of homes are put up for sale.

The fact that each respondent provided eight data points creates the potential for correlation. Accordingly, we used a random effects panel data estimator. After experimenting with a wide range of specifications, we found that logarithmic transformations of *HOUSE* and *DIST* best fit the data. The reasoning behind this specification is the same as for the hedonic model – incremental increases should have diminishing effects on choice.

The conditional logit specification is summarized in Table 7. The environmental conditions are distinguished using effects coding (Adamowicz *et al.*, 1994, 1997),²² and the status quo (*CURR*) is the omitted condition. Its coefficient can be recovered as the sum of the negative coefficients of the other conditions. A Wald χ^2 test indicates that the model is significant at the 1% level. The log likelihood is significantly higher than the general conditional logit: (-998.38 versus -1073.82). The log likelihood test for correlation within individuals is significant at the 1% level.²³

Because of the interaction terms, the composite effect of individual variables is difficult to discern from the estimation results. Table 8 reports the composite effects for *DIST*, *FAMILY*, and changes in environmental quality at the AOC, along with their significance levels. The composite effect of *DIST* is significantly positive when the environmental condition is *CURR*, and even more so for *ADD*, but not statistically significant for *PART* or *FULL*. These results imply that reducing or eliminating the environmental threat posed by the river would neutralize the value of distance in residential choice. The composite effect of *FAMILY* is not statistically significant for all environmental conditions.

²² Effects coding is accomplished in this case by defining three dummy variables, D1, D2, and D3. The respective environmental conditions are represented by the following combinations of dummy variables: *ADD* = (1,0,0); *CURR* = (-1,-1,-1); *PART* = (0,1,0); and *FULL* = (0,0,1). Thus, the coefficient for *CURR* equals the sum of the negative values of the coefficients of *ADD*, *PART*, and *FULL*.

²³ Likelihood ratio test of $\rho=0$: $\chi^2(1)=150.88$, $\text{Prob} > \chi^2 = 0.0000$. When $\rho=0$, the panel-level variance component in the error terms is unimportant and the random effect conditional logit estimator is not different from the ordinary conditional logit estimator. Here, $\rho=0$ is rejected.

The estimates in Table 7 are the basis for calculating WTP. Tables 9 and 10 report WTP estimates for changes in environmental quality at the AOC, and WTP for moving further from the AOC, respectively. In Table 9, WTP estimates are computed in two ways for comparison purposes. First, we fully enumerate the response sample to calculate mean and median utility values and then convert these values to WTP measures using equation (18). The mean and median estimate of the WTP for the sample using this approach is reported in the second and third column of Table 9. A second approach is to simply evaluate the utility function for the “mean household.” In other words, the utility value is computed holding all elements of the utility function constant at the sample means (or medians) for the characteristics. WTP estimates based on this approach are reported in the right-most two columns of Table 9. Aggregate net benefits are also reported, and are calculated by multiplying the mean and median values of WTP by the number of households in the population.

As indicated in Table 9, the WTP estimates are of similar magnitudes regardless of which computational approach is used. The WTP for complete cleanup of the AOC from the current condition (*FULL*) is substantial. For the household with mean sample characteristics,²⁴ the WTP for full cleanup is \$11,408. This estimate is somewhat more conservative than the estimates based on full sample enumeration. The WTP to avoid additional pollution at the AOC, again for the mean household, is \$25,120. Note, the WTP for partial cleanup is negative, although based on a composite marginal effect that is not significantly different from zero. Thus, we do not report aggregate benefits for partial cleanup. Aggregate net benefits for full cleanup range from approximately \$600 million to \$700 million. Given the similarity between the estimates based

²⁴ The mean sample values for attributes and demographics in the model are: a household income of 67,348, a family size of 2.72 members, a current house-size of 1,483 square feet, and a distance of 2.53 miles from the AOC.

on full-sample enumeration and those based on mean-household characteristics, we focus the remaining discussion on the latter WTP estimates.

Table 9 also reports WTP estimates based on just the sample located to the south of the AOC. The per-household estimates of WTP are somewhat smaller than those based on the entire sample, and the aggregate net benefits for full cleanup are between \$225 million and \$260 million, less than half of the total net benefits. (Approximately 43% of the households in the study area are south of the AOC.) Estimates based on just the sample to the south of the AOC will be compared to the hedonic estimates, as only significant price impacts were found south of the AOC in the hedonic model.

Table 10 reports the net benefits for relocation, calculated for the household with mean and median characteristics. In table 10, four initial distances are considered, ranging from 0.5 miles to 3.0 miles. The net benefits are thus the additional WTP for a home located at the boundary (5 miles) as compared to the initial distance, holding environmental quality constant at the current level of contamination. For a representative household located 0.5 miles from the river, the estimate of WTP to reduce exposure through moving to the study area boundary is \$5,441, or approximately 6% of the mean house price for the sample. WTP falls relatively quickly as the initial distance to the AOC is increased. For a home located initially at 2.5 miles from the AOC, the value of moving to the boundary is \$1,638 or less than 2% of mean house values. Comparisons of these estimates to those for changes in environmental quality are considered next.

HYPOTHESIS TESTS

H₀₁: Equivalency of Proximity Discount to WTP for Full Cleanup in Conjoint Choices

$$\text{Test: } \text{NB}^{\text{CJ}} \{ D_0, (\bar{E} - E_0), \underline{Z} \} = \text{NB}^{\text{CJ}} \{ (\bar{D} - D_0), E_0, \underline{Z} \}$$

Our first conjecture is that the net benefits from moving a household to the boundary of the exposure zone is equivalent to the willingness to pay for elimination of the disamenity. This is the essential interpretation of the hedonic measure of value. We test this hypothesis using just the conjoint choice data initially. To test H₀₁, the initial environmental condition chosen, E₀, is the current condition of the AOC. An initial distance to the AOC, D₀, must also be chosen. We use four initial conditions for distance: 0.5, 1.5, 2.5 and 3.0 miles from the AOC. Table 11 reports two sets of net benefit estimates for each initial condition. The first is the WTP estimate for full cleanup of the AOC, holding distance to the AOC constant at each of the specified distances, and holding all other attributes/demographics constant at the mean value for the sample – i.e., $\text{NB}^{\text{CJ}} \{ D_0, (\bar{E} - E_0), \underline{Z} \}$. The second computes the net benefits for moving a house from its initial distance to the boundary distance (five miles), holding environmental condition constant at the current AOC contamination, and holding all other attributes/demographics constant at the sample means – i.e., $\text{NB}^{\text{CJ}} \{ (\bar{D} - D_0), E_0, \underline{Z} \}$. Table 11 also reports the t-statistic associated with the test of the null hypothesis that the two net benefit estimates are equal.

As indicated in Table 11, we cannot reject the null hypothesis of equality of net benefit for all initial distances at the 10% level. Our theoretical model – and the hedonic method for this type of application – is based on the notion that the value of obtaining a no-exposure condition for housing should be the same regardless of the means by which freedom from residential exposure is achieved – either through moving outside the impact zone (holding all else constant about the housing) or through removal of the contamination itself. However, our results thus far

indicate that survey respondents revealed different values for explicit full-cleanup at a contaminated site versus moving far away from that site (and leaving its contamination unchanged).

Differences in the value of eliminating exposure may be due to upward bias in the stated value of cleanup. First, it could be that non-use values were expressed through the choices made over cleanup, even though the context was the purchase of a home which should not reflect non-use values. To test this hypothesis, we compute the estimated WTP for cleanup for a home located at the boundary of our study area, five miles. For a household with mean demographics and house attributes, the WTP for cleanup, given that their house is five miles from the AOC is \$10,651 and is significantly different from zero at the 1% level. This result indicates that individuals included nonuse values in their responses or that 5 miles is not considered a “safe” distance from the AOC. The latter explanation seems implausible given the nature of the contamination.

The results may also stem from a downward bias in the stated preference for distance. We may not have fully captured the importance of distance, \bar{D} , such that $\bar{X} = f(\bar{D}, E_0)$. Our survey design increased proximity to the river by up to two miles, and increased distance from the AOC by up to one mile. However, our extrapolation from the mean distance, as well as distances closer to the AOC, exceed these changes and may be considered “out of sample.” Another related reason for the differences might be the impact of transactions costs on responses. Although we explicitly told residents to ignore transactions costs, the current home was favored to the alternative so much so that nearly half of the hypothetical homes that were putatively “superior” in terms of price, size, and exposure were not selected. (See appendix tables A.5 and

A.6). The perception of transactions costs would increase the price differential required to persuade respondents to select a hypothetical home.

H₀₂: The Hedonic Proximity Discount Approximates the Conjoint Proximity Discount

$$\text{Test: } \text{NB}^{\text{CJ}} \{(\bar{D} - D_0), E_0, \underline{Z}\} = \text{NB}^{\text{H}} \{(\bar{D} - D_0), E_0, \underline{Z}\}$$

Although the conjoint NB for cleanup appears to be significantly greater than the estimated conjoint net benefit for removal of exposure through increased distance, it is still of interest to compare the conjoint and the hedonic estimates of the proximity discount. Results related to this hypothesis are presented in Table 12. The net benefits of relocation in the hedonic model are approximately three times as large as the estimates from the conjoint survey. However, we cannot reject the null that the two estimates are equivalent at the 10% level. We can reject the null at 11% level, however. We return to a discussion of these results after presenting the results for the last hypothesis test.

H₀₃: The Hedonic Proximity Discount Approximates Conjoint Cleanup Net Benefits

$$\text{Test: } \text{NB}^{\text{CJ}} \{D_0, (\bar{E} - E_0), \underline{Z}\} = \text{NB}^{\text{H}} \{(\bar{D} - D_0), E_0, \underline{Z}\}$$

Of particular interest are the results for our third hypothesis. As indicated in Table 13, the hedonic proximity discount estimates are quite similar in magnitude to the conjoint estimates for full cleanup at locations up to approximately three miles from the AOC. The similarity in the net benefit estimates for properties close to the AOC is encouraging, supporting the use of hedonic proximity NB estimates as a proxy for the value of site cleanup. The “boundary distance” at which there is perceived exposure to an environmental condition is an empirical question. Our hedonic analysis suggests that, if market transactions accurately reflect perceived

exposures, the AOC has little effect on property values beyond two miles from the AOC (for properties to the south of the AOC). When comparing hedonic price discounts to stated preference values for site cleanup, we find no significant differences across the two methods within 2.5 miles of the AOC. This result suggests that hedonic models estimating net benefits through “proximity discount elimination” are capable of approximating the net benefits of site cleanup, the usual policy target.

In addition, these results provide some external validity for choice surveys, although the choice survey results appear to be less accurate at revealing the extent of the market. In other words, the marginal tradeoffs made in the surveys between cleanup, distance and house price reflect observed market transactions under particular conditions – that the households are located within the market-observed impact zone (approximately 2 miles from the AOC). However, the survey WTP estimates vary little outside the market-observed impact zone. This is akin to recent experimental evidence that suggests hypothetical choice surveys are capable of estimating marginal tradeoffs quite well, but do not accurately predict the extent of the market (Taylor, *et al*, 2006).

DISCUSSION AND CONCLUSIONS

Our theoretical model is predicated on the notion that households value reductions in toxic environmental exposures. Thus, a contaminated site that would otherwise have no external positive or negative effects on surrounding property values would be observed to generate negative impacts due its contaminated condition. If households value reductions in exposures, then the question arises of whether or not all paths that lead to a reduction in exposure are valued

equally. Within the context of purchasing a home, and the site-specific amenities associated with the home, our theoretical model suggests that elimination of exposure at a home should be valued equally no matter what path leads to that elimination – whether it be cleanup of the contaminated site or moving to a “safe” distance from the site. This hypothesis critically hinges on an ability to hold all else constant about housing when eliminating exposure.

We conduct a conjoint survey that parallels a market condition in Buffalo NY to allow us to examine the aforementioned proposition. While our results are certainly not unequivocal, they do provide support for valuing site cleanup *via* hedonic estimates of proximity discounts. The converse interpretation of these results are that there is encouraging evidence that choice surveys using a property value context provide cleanup value estimates that approximate theoretically consistent values estimated from market data. However, we caution that our results also suggest that stated preferences may not accurately reveal the extent of the market – a matter of great importance when computing aggregate net benefits.

Less promising are the results related to the conjoint survey estimates of the value of increasing distance from a contaminated site. The conjoint estimates for moving to five miles from the AOC are significantly different than the conjoint estimates for the value of full cleanup, and are substantially smaller than, although not significantly different than the estimated hedonic values for distance. These results may suggest that when presented with choices between distance and cleanup in a survey context, respondents find distance a poor substitute for avoiding exposure as compared to site cleanup. Nonetheless, actual market choices related to distance from a contaminated site appear to closely parallel stated preferences for site cleanup.

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Figure 1. Hedonic Price and Bid Functions

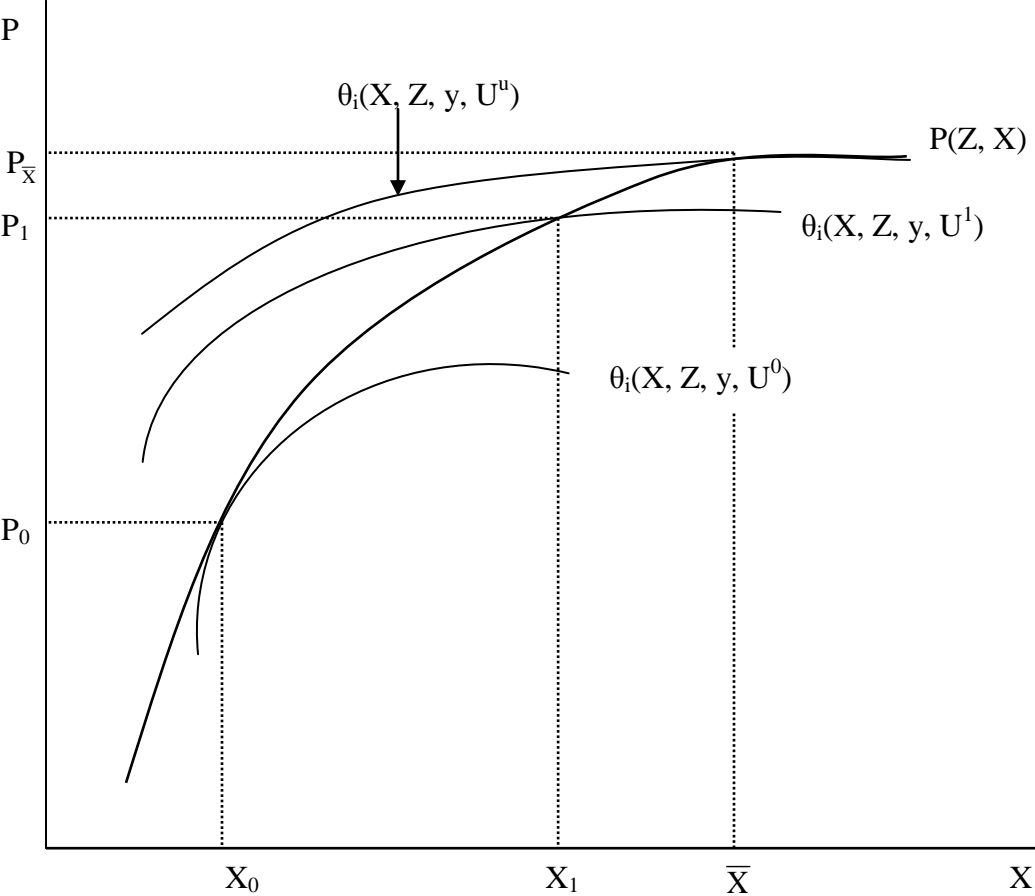


Figure 2. Property Sales within 5 Radial Miles of the Buffalo River Area of

Figure 2. Properties Sold, and Properties Surveyed, within 5 Radial Miles of the Buffalo River Area of Concern, 2002-2004

<<<Insert Here>>>

Figure 3. Representative Conjoint Choice Question

Imagine your current home modified as follows:

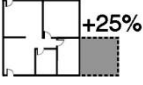


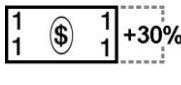
House size	Environmental condition of Lower Buffalo River	Proximity to Lower Buffalo River	Home price	
	<p>Clean</p> 	<p>1 mi. farther</p> 		<p style="text-align: center;">Your Choice: (check one)</p> <p><input type="checkbox"/> Modified home</p> <p><input type="checkbox"/> Current home</p>

Figure 4. Percentage Price Discounts per 1/10th mile, Owner-Occupied Dwellings South and within Five Miles of the Buffalo River AOC

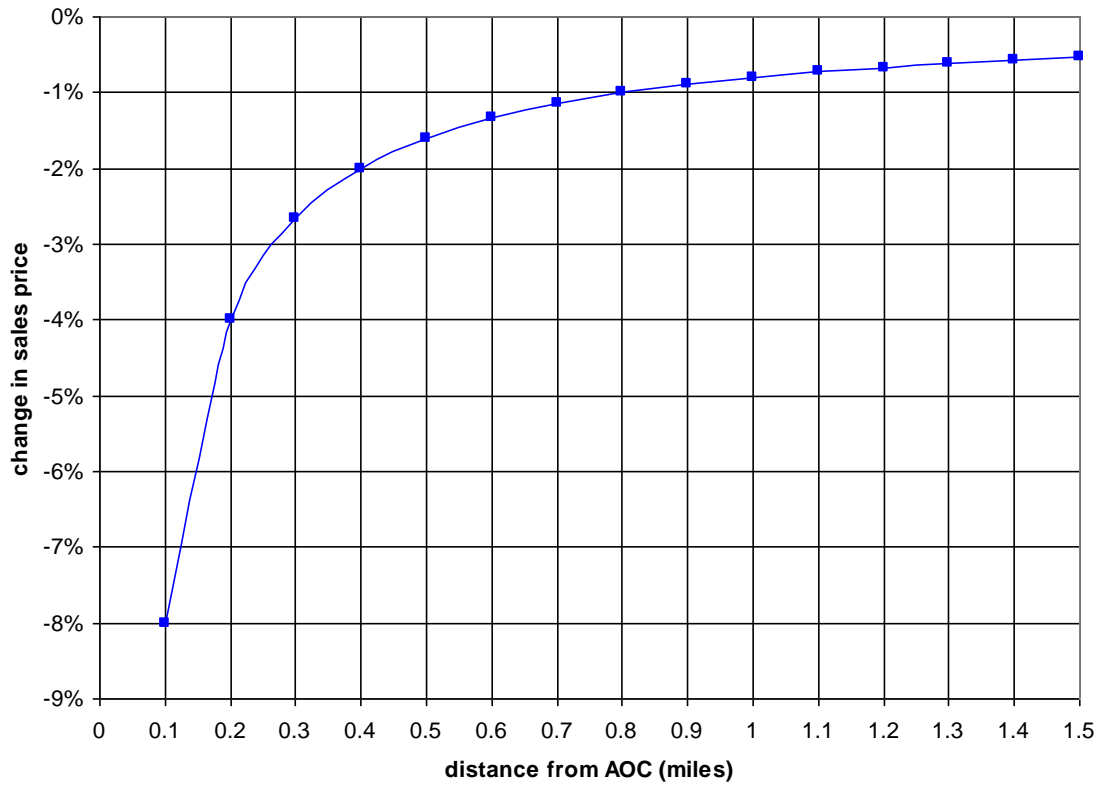


Table 1. Census Statistics for Communities Surrounding the Buffalo River AOC

Variables	Jurisdictions near Buffalo River, NY, AOC							
	Buffalo	Cheektowaga	Sloan	Hamburg	Blasdell	Lackawanna	West Seneca	Total
Population (2003)*	282,864	91,554	3,576	56,648	2,578	18,394	45,032	500,646
Median Age (years)	33.6	40.9	41.7	38.9	36.5	37.5	41.1	**36.4
Total Housing Units	145,574	41,910	1,789	22,833	1,282	8,951	18,982	241,321
Occupied Housing Units	122,720	40,045	1,680	21,999	1,201	8,192	18,328	214,165
Owner-occupied Housing Units	33,030	24,322	1,223	14,267	667	3,303	12,626	89,438
Median Value, Owner-occupied Units (2004 \$)	59,300	81,800	68,600	95,700	76,600	73,600	95,200	**77,077
Average Household Size (ft ²)	2.29	2.32	2.89	2.51	2.26	2.3	2.47	**2.36
Median Household Income (1999)	30,614	38,121	29,420	47,888	43,846	29,354	46,278	**34,798

Source: U.S Bureau of the Census (2000), except as noted

* American Community Survey, U.S. Bureau of the Census (2003)

** Weighted Average of the Median

Table 2. Variable Description for Buffalo Area Hedonic Data

Housing Characteristics	
saleprice	sales price of parcel in 2004 dollars
acres (acres2)	acreage of parcel (number of acres squared)
age (age2)	age of home at time of sale (age of home squared)
sfla	square feet of living area
bedrooms	number of bedrooms
fullbaths	number of full-bathrooms
halfbaths	number of half-bathrooms
grade_ab	dummy variable =1 if tax assessor assigns a quality grade of “a” or “b” (on a scale of a, b, c, d, e, with a being the highest quality)
grade_de	dummy variable =1 if tax assessor assigns a quality grade of “d” or “e” (on a scale of a, b, c, d, e, with a being the highest quality)
grade_c	dummy variable =1 if tax assessor assigns a quality grade of “c” (on a scale of a, b, c, d, e, with a being the highest quality) – this category is omitted from the models.
cape	dummy variable =1 if home is described as a cape-cod style
colonial	dummy variable =1 if home is described as a colonial style
oldstyle	dummy variable =1 if home is described as “old-style”
otherstyle	dummy variable =1 if home is described other than the three categories listed above. Category contains mainly ranch-style homes and is omitted from the model.
fullbasement	dummy variable =1 if the home has a full basement
fireplace	dummy variable =1 if the home has at least one fireplace
Location Variables	
Buffalo_N	dummy variable =1 if the parcel is in the City of Buffalo, north of AOC
Buffalo_S	dummy variable =1 if the parcel is in the City of Buffalo, south of AOC
Cheektowaga/Sloan	dummy variable =1 if the parcel is located in Cheektowaga or Sloan
West Seneca	dummy variable =1 if the parcel is located in West Seneca
Lackawanna	dummy variable =1 if the parcel is located in Lackawanna
Hamburg/Blasdell	dummy variable =1 if the parcel is located in Hamburg or Blasdell
north	dummy variable =1 if the parcel is located north of the Buffalo River (regardless of which jurisdiction the parcel is located in)
Census Tract Identifiers	A series of dummy variables indicating the census tract in which each property is located. Parcels in our census tracts lie in 118 different census tracts – these variables are not reported in the models for succinctness.
Proximity Variables (all distances measured in miles)	
cbd	Distance to the central business district
delpark	Distance to Delaware Park , a significant park in the northern edge of the study area
park	Distance to the closest park
rail	Distance to the closest segment of a rail line
stream	Distance to the nearest stream, other than the AOC
airport	Distance to the Buffalo Airport
hws	Distance to the nearest hazardous waste site
hwy	Distance to the nearest point on a major highway
hwyx	Distance to the nearest highway interchange
shore	Distance to the shoreline of Lake Erie
AOC	Distance to the AOC

Table 3. Summary Statistics for Buffalo Area Hedonic Data

Housing Characteristics				
	Mean	Std. Dev.	Min. Value	Max. Value
saleprice	100,006.4	74,347.3	10,201	1,092,945
acres	0.184	0.241	0.015	4.583
age	60.82	29.11	0	204
sfla	1,543.43	635.08	480	9,717
bedrooms	3.22	0.81	1	10
fullbaths	1.25	0.56	1	7
halfbaths	0.34	0.49	0	5
grade_ab	0.07	0.26	0	1
grade_de	0.03	0.17	0	1
cape	0.21	0.40	0	1
colonial	0.09	0.28	0	1
oldstyle	0.41	0.49	0	1
fullbasement	0.85	0.35	0	1
fireplace	0.23	0.42	0	1
Location Variables				
	N	% of total		
	(total=3,474)			
Buffalo_N	1,041	29.97		
Buffalo_S	427	12.29		
Cheektowaga/Sloan	794	22.86		
West Seneca	881	25.36		
Lackawanna	261	7.51		
Hamburg/Blasdell	70	2.01		
North	1,633	47.01		
Proximity Variables (Non-AOC)				
	Mean	Std. Dev.	Min. Value	Max. Value
cbd	5.01	1.71	0.27	8.22
delpark	4.93	2.71	0.02	9.41
park	0.55	0.34	0.00	2.29
rail	0.57	0.40	0.01	1.99
stream	1.57	1.71	0.01	5.68
airport	5.79	1.99	1.32	10.73
hws	0.66	0.31	0.01	1.94
hwy	0.77	0.46	0.02	2.17
hwyx	0.95	0.46	0.04	2.31
shore	3.70	1.74	0.13	7.09
Proximity to AOC				
	Mean	Std. Dev.	Min. Value	Max. Value
all properties:	3.05	1.27	0.08	4.99
north of AOC:	3.15	1.20	0.10	4.99
south of AOC:	2.96	1.32	0.08	4.86

Table 4. Home Attributes and Levels for Survey Choice Questions

	<u>Attribute</u>			
	Home Size	Environmental Condition of River	Proximity to River	Home Price
Levels	+ 25%	Full cleanup	2 miles closer	+30%
	+15%	Partial cleanup	1 mile closer	+15%
	No change	No change	No change	No change
	-15%	Additional Pollution	1 mile further	-10%

Table 5. Survey Distribution and Response Summary

Jurisdiction	Jurisdiction ID	Mailed	Undeli- verable	Not Returned	Mail Response	Internet Response	Final Usable ^c
Buffalo	1	383	38	206	127	8	126
Cheektowaga ^a	2	208	8	121	71	6	67
Hamburg ^b	3	26	2	15	8	1	9
Lackawanna	4	59	4	26	28	1	26
West Seneca	5	174	11	94	60	7	66
Total^d		850	63	462	294	23	294

^a Cheektowaga includes Sloan.

^b Hamburg includes Blasdell.

^c 20 observations were lost because distance could not be estimated by GIS. In addition, three respondents did not answer any house choice questions.

^d Total response=317. Total surveys successfully delivered= 787.
Response rate = 317/787= 40.2%

Table 6. Hedonic Price Analysis Results

Variable Name	Coefficient Estimate	Standard Error	Variable Name	Coefficient Estimate	Standard Error
Housing Characteristics			Proximity Variables (non-AOC)		
acres	29,357***	9,510	lncbd_n	-15,161	16,621
acres2	-8,493***	3,306	lnelpark_n	-17,458***	6,235
age	937***	294	lnpark_s	372	894
age2	-12.10***	3.96	lnrail	643	1,006
age3	0.04**	0.02	lnrail*north	2,891	2,121
sfla	28.48***	3.23	lnstream	-1,272	1,029
sfla*north	27.20***	6.11	lnstream*north	1,936	3,787
bedrooms	-2,353*	1,297	lnairport	-21,681	14,903
fullbaths	16,721***	3,056	lnairport*north	-6,822	20,810
halfbaths	6,010***	1,732	lnhws	2,660**	1,405
grade_ab	64,956***	6,739	lnhws*north	5,371	3,920
grade_de	-3,982***	2,777	lnhwy	2,610	1,674
cape	-8,780***	1,647	lnhwy*north	1,908	2,846
colonial	14,255***	3,764	lnhwyx	-2,031	2,505
oldstyle	-21,287***	4,057	lnhwyx*north	-14,113***	5,333
fullbasement	2,948	1,846	lnshore	-3,658***	7,642
fireplace	4,609**	1,889	lnshore*north	26,668**	14,373
Location Dummy Variables^a			Proximity to AOC		
Buffalo_S	-270,359*	157,679	lnaoc	6,770***	2,598
Cheektowaga	-207,798	147,340	lnaoc*north	-5,585	7,968
West Seneca	-274,997*	157,460			
Lackawanna	-269,223*	157,578			
north	-170,662	266,023			
				N = 3,474	
				R ² = 0.8307	

*** Significant at the 1% level.

** Significant at the 5% level.

* Significant at the 10% level.

^a Coefficient estimates for the 118 dummy variables indicating the census tracts in which houses were located are not reported for succinctness. The dummy variable for Hamburg is the omitted category.

Table 7. Random-Effects Conditional Logit Estimation of RUM

Variable	Coefficient	Std. Err.	z	P>z
<i>ASC</i>	1.1489***	0.1659857	6.92	0.00
<i>lnHOUSE</i>	2.15228	1.393722	1.54	0.12
<i>INCOMEx lnHOUSE</i>	0.000036**	0.0000181	1.99	0.05
<i>FAMILY x ln INCOME</i>	0.519247	0.376185	1.38	0.17
<i>ADD</i>	-1.5735***	0.4784356	-3.29	0.00
<i>INCOME x ADD</i>	-0.000005	0.00000637	-0.86	0.39
<i>FAMILY x ADD</i>	0.165449	0.1154969	1.43	0.15
<i>PART</i>	0.390134	0.3520677	1.11	0.27
<i>INCOME x PART</i>	0.000001	0.00000486	0.21	0.84
<i>FAMILY x PART</i>	-0.104616	0.0921358	-1.14	0.26
<i>FULL</i>	1.2137***	0.3436655	3.53	0.00
<i>INCOME x FULL</i>	0.000002	0.0000046	0.54	0.59
<i>FAMILY x FULL</i>	-0.14516	0.0904646	-1.6	0.11
<i>lnDIST</i>	0.34430***	0.1068717	3.22	0.00
<i>LnDIST x ADD</i>	0.4863**	0.2527134	1.92	0.05
<i>LnDIST x PART</i>	-0.30866**	0.1376225	-2.24	0.03
<i>lnDIST x FULL</i>	-0.196546	0.1218464	-1.61	0.11
<i>FAMILY x lnDIST</i>	-0.06403**	0.0281501	-2.27	0.02
<i>FAMILY x lnDIST x ADD</i>	-0.08760	0.0595527	-1.47	0.14
<i>FAMILY x lnDIST x PART</i>	0.074000*	0.0432606	1.71	0.09
<i>FAMILY x lnDIST x FULL</i>	0.037559	0.0349905	1.07	0.28
<i>Y-PRICE</i>	0.00092***	0.0000943	9.86	0.00
<i>INCOME x (Y-PRICE)</i>	-5.42E-09***	1.14E-09	-4.75	0.00

Log likelihood = -998.38

No. obs. = 4,272

No.groups = 281

Wald $\chi^2(22) = 224.54$

Prob > $\chi^2 = 0$

*** Significant at the 1% level.

** Significant at the 5% level.

* Significant at the 10% level.

Table 8. Composite Marginal Effects of *DIST* and *FAMILY* by Environmental Condition, and of a Change in Environmental Condition^a

A. DIST, holding FAMILY at the sample mean and Environmental Condition constant

Environmental Condition	Composite		95% Confidence Boundaries	
	Coefficient	p-value	Lower	Upper
<i>FULL</i>	0.0757	0.1082	-0.0166	0.1681
<i>PART</i>	0.0627	0.2429	-0.0425	0.1681
<i>CURR</i>	0.1238**	0.0296	0.0122	0.2354
<i>ADD</i>	0.1482***	0.0049	0.1268	0.7096

B. FAMILY, holding DIST at sample mean and Environmental Condition constant

Environmental Condition	Composite		95% Confidence Boundaries	
	Coefficient	p-value	Lower	Upper
<i>FULL</i>	3.5955	0.1867	-1.7420	8.9332
<i>PART</i>	3.6454	0.1786	-1.6670	8.9579
<i>CURR</i>	3.8093	0.1629	-1.5415	9.1603
<i>ADD</i>	3.8742	0.1517	-1.4227	9.1711

C. Change in Environmental Condition from CURR, holding FAMILY and DIST constant at their sample means

New Environ. Condition	Composite		95% Confidence Boundaries	
	Coefficient	p-value	Lower	Upper
<i>FULL</i>	0.5977***	0.0000	0.2353	0.9602
<i>PART</i>	-0.1704	0.3680	-0.5432	0.2022
<i>ADD</i>	-13162***	0.0000	-1.7213	-0.9112

^a Confidence intervals computed using the Delta method (Green 2003, Oehlert 1992)

*** Significant at the 1% level.

** Significant at the 5% level.

* Significant at the 10% level.

Table 9. Conjoint Net Benefits for Environmental Change from *CURRENT* holding *DIST* constant, by Impact Sector^a

New Environmental Condition	Estimates Based on Sample Enumeration		Estimates Based on Mean or Median Household	
	Mean NB	Median NB	Mean NB	Median NB
	(% of Mean House Value) [Aggregate Net Benefit] ^b	(% of Median House Value) [Aggregate Net Benefit] ^b	(% of Mean House Value) [Aggregate Net Benefit] ^b	(% of Median House Value) [Aggregate Net Benefit] ^b
All Single Family Homes Within Five Miles of AOC				
<i>ADD</i>	-\$29,874 (-32.6%) [-\$1,572]	-\$22,047 (-28.3%) [-\$1,160]	-\$25,120 (-27.4%) [-\$1,322]	-\$21,779 (-29.4%) [-\$1,204]
<i>PART</i> ^c	-\$3,552	-\$3,321	-\$3,253	-\$1,951
<i>FULL</i>	\$13,278 (14.5%) [\$698]	\$12,204 (15.2%) [\$624]	\$11,408 (12.4%) [\$600]	\$13,071 (16.7%) [\$687]
All Single Family Homes South of the AOC and Within Five Miles				
<i>ADD</i>	-\$24,550 (-30.1%) [-\$538]	-\$21,624 (-28.1%) [-\$473]	-\$23,369 (-28.7%) [-\$538]	-\$21,622 (-28.1%) [-\$498]
<i>PART</i> ^c	-\$3,326	-\$3,336	-\$3,201	-\$3,699
<i>FULL</i>	\$11,421 (14.0%) [\$250]	\$10,324 (13.4%) [\$226]	\$10,818 (13.2%) [\$249]	\$9,748 (12.6%) [\$224]

^a All values are 2004 dollars. Mean and median house values for the full response sample were \$91,568 and \$77,838, respectively. The comparable values south of the AOC were \$84,619 and \$79,433.

^b Aggregate benefits are the per-household benefit (mean or median) multiplied by the number of households in the impact area (53,628 households in the entire study area and 23,037 south of the AOC), and are reported in millions of dollars.

^c As shown in Table 8, Panel C, the estimated composite marginal effect for *PART* is not significantly different from zero at the 10% level, thus we do not compute percentage or aggregate benefits.

Table 10. Conjoint Net Benefits for Relocation from D_0 to \bar{D} holding Environmental Condition at *CURRENT*, by Impact Sector.^a

Estimates Based on Mean or Median Household^b		
Initial Distance (D_0)	Mean NB (% of Mean House Value)	Median NB (% of Median House Value)
All Single Family Homes Within Five Miles of AOC		
0.5 miles	\$5,441 (5.9%)	\$7,929 (10.1%)
1.5 miles	\$2,845 (3.1%)	\$4,146 (5.3%)
2.5 miles	\$1,638 (1.8%)	\$2,386 (3.0%)
3.0 miles	\$1,207 (1.3%)	\$1,759 (2.2%)
All Single Family Homes South of the AOC and Within Five Miles		
0.5 miles	\$5,116 (6.2%)	\$4,154 (5.4%)
1.5 miles	\$2,675 (3.2%)	\$2,172 (2.8%)
2.5 miles	\$1,540 (1.8%)	\$1,250 (1.6%)
3.0 miles	\$1,135 (1.3%)	\$921 (1.1%)

^a All values are 2004 dollars. Mean and median house values for the full response sample were \$91,568 and \$77,838, respectively. The comparable values south of the AOC were \$84,619 and \$79,433.

^b Compared to the overall response sample, the southern sub-sample has lower mean (\$25,569 vs. \$30,274) and median (\$23,333 vs. \$25,000) per-capita incomes, similar mean household sizes (2.76 vs. 2.72), and much larger median household sizes (3 vs. 2). These factors contribute to larger median estimates for the overall sample and larger mean estimates for the southern sub-sample.

Table 11. Comparison of Conjoint NB for Full Cleanup at Current Location to Conjoint NB for Relocation to the Impact Boundary given the Current Environmental Condition

$$\text{Test of } H_{01}: \text{NB}^{\text{CJ}} \{(\bar{D} - D_0), E_0, \underline{Z}\} = \text{NB}^{\text{CJ}} \{D_0, (\bar{E} - E_0), \underline{Z}\}$$

Variable	Net Benefit (WTP) (std. dev.) ^a	t-statistic ^b (p-value)
D₀ = 0.5 miles		
NB for <i>FULL</i>	\$12,765 (4,315)	1.7023
NB for Relocation to 5.0 miles	\$5,441 (2,566)	(0.0892)
D₀ = 1.5 miles		
NB for <i>FULL</i>	\$11,756 (4,304)	2.4475
NB for Relocation to 5.0 miles	\$2,845 (1,341)	(0.0147)
D₀ = 2.5 miles		
NB for <i>FULL</i>	\$11,287 (4,464)	2.6486
NB for Relocation to 5.0 miles	\$1,638 (772)	(0.0083)
D₀ = 3.0 miles		
NB for <i>FULL</i>	\$11,120 (4,544)	2.6825
NB for Relocation to 5.0 miles	\$1,207 (569)	(0.0075)

^a Standard errors are obtained using the Delta Method.

^b T-statistic for the null hypothesis that the net benefit estimate for FULL equals the net benefit estimate for relocation to 5.0 miles.

Table 12. Comparison of Conjoint NB of Relocation to the Hedonic Price Discount

$$\text{Test of } H_{02}: \text{NB}^{\text{CJ}} \{(\bar{D} - D_0), E_0, \underline{Z}\} = \text{NB}^{\text{H}} \{(\bar{D} - D_0), E_0, \underline{Z}\}$$

Benefit Estimate Source	Mean ^a (std. error)	t-statistic ^b (p-value)
D₀ = 0.5 miles		
Hedonic NB for Relocation to 5.0 miles	\$15,588 (5,982)	1.6173
Conjoint NB for Relocation to 5.0 miles	\$5,116 (2,476)	(0.1064)
D₀ = 1.5 miles		
Hedonic NB for Relocation to 5.0 miles	\$8,151 (3,127)	1.6178
Conjoint NB for Relocation to 5.0 miles	\$2,675 (1,295)	(0.1052)
D₀ = 2.5 miles		
Hedonic NB for Relocation to 5.0 miles	\$4,692 (1,801)	1.6169
Conjoint NB for Relocation to 5.0 miles	\$1,540 (745)	(0.1070)
D₀ = 3.0 miles		
Hedonic NB for Relocation to 5.0 miles	\$3,458 (1,327)	1.6173
Conjoint NB for Relocation to 5.0 miles	\$1,135 (549)	(0.1064)

^a Net benefit estimates and t-tests are based on the smaller, southern sector for which hedonic price estimates indicated impacts of proximity to the AOC. Standard errors for conjoint estimates are obtained using the Delta Method. The conjoint estimates are evaluated for the household with mean demographic and attribute data.

^b T-statistic for the null hypothesis that the Hedonic NB estimate for relocation to 5.0 miles is equal to the Conjoint NB estimate for relocation to 5.0 miles.

Table 13. Comparison of Conjoint NB for Cleanup to the Hedonic Price Discount

$$\text{Test of } H_{03}: \text{NB}^{\text{CJ}} \{ D_0, (\bar{E} - E_0), \underline{Z} \} = \text{NB}^{\text{H}} \{ (\bar{D} - D_0), E_0, \underline{Z} \}$$

Benefit Estimate Source	Net Benefit ^a (std. error)	t-statistic ^b (p-value)
D₀ = 0.5 miles		
Hedonic NB for Relocation to 5.0 miles	\$15,588 (5,982)	0.51 (0.6100)
Conjoint NB for <i>FULL</i>	\$12,107 (3,355)	
D₀ = 1.5 miles		
Hedonic NB for Relocation to 5.0 miles	\$8,151 (3,127)	0.67 (0.5082)
Conjoint NB for <i>FULL</i>	\$11,181 (3,289)	
D₀ = 2.5 miles		
Hedonic NB for Relocation to 5.0 miles	\$4,692 (1,801)	1.55 (0.1212)
Conjoint NB for <i>FULL</i>	\$10,751 (3,457)	
D₀ = 3.0 miles		
Hedonic NB for Relocation to 5.0 miles	\$3,458 (1,327)	1.89 (0.0588)
Conjoint NB for <i>FULL</i>	\$10,597 (3,544)	

^a Net benefit estimates and t-tests are based on the smaller, southern sector for which hedonic price estimates indicated impacts of proximity to the AOC. Standard errors for conjoint estimates are obtained using the Delta Method. The conjoint estimates are evaluated for the household with mean demographic and attribute data.

^b T-statistic for the null hypothesis that the Hedonic NB estimate for relocation to 5.0 miles is equal to the Conjoint NB estimate for *FULL*.