BENEFITS OF HAZARDOUS WASTE CLEANUP: NEW EVIDENCE FROM SURVEY- AND MARKET-BASED PROPERTY VALUE APPROACHES

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This article compares the discrete choice random utility model and the hedonic property value model in estimating the benefits of cleaning up Waukegan Harbor, a Superfund site on the Great Lakes. The study uses survey-based conjoint choice data on housing preferences and market data on housing transactions. The research finds that the benefit estimates for different levels of cleanup are quite comparable between the models. The estimates compare very well with those of some previous studies. The results of the study suggest that tax increment financing by the local government is a feasible option to fund cleanup.

I. INTRODUCTION

Studies have shown that community knowledge of the presence of a potentially hazardous toxic site results in significant value depreciation of nearby real estate. A majority of these studies involve ex post hedonic analysis of the real estate market with data from before and after community knowledge of the change in site conditions.[1] In the absence of any change in community perceptions, studying the welfare implications of cleaning up a toxic site would involve investigating the differential impact of the site on the properties across nearby locations. Unfortunately, very few studies have systematically pursued this line of research, despite its policy relevance, especially at the level of local governments. In the United States, the vast majority of Superfund sites await cleanup, while the local economies lag behind. Significant costs of cleaning up often come in the way of an early remedial action (Hamilton and Viscusi, 1999).[2] This article focuses on one such hazardous site and investigates its differential impact on the properties across nearby locations to estimate the benefits of a proposed Superfund cleanup.

With a view to improve reliability, this article presents applications of two different models: the survey-based random utility model (RUM) and the market-based hedonic model. The

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1. Michaels and Smith (1990), Kohlhase (1991), and Kiel (1995) have shown significant value change in nearby residential properties after a site is identified as hazardous. Ihlanfeldt and Taylor (2004) show similar evidence in the case of commercial properties. Gayer et al. (2000) show significant value appreciation when public perception on a hazardous site changes for the better after the Environmental Protection Agency (EPA) releases factual information on site conditions that reduce uncertainties.

2. As of May 13, 2004, there were 1,237 final sites under the National Priority List (NPL) waiting to be cleaned up (see http://www.epa.gov/superfund/sites/query/queryhtm/npltotal.htm, accessed May 24, 2004). In a recent study, Probst and Sherman (2004) find that the average cost per site in the past has been $2.1 million and the expected future cost per site is $22.26 million.

ABBREVIATIONS

AOC: Area of Concern
CV: Compensating Variation
EPA: Environmental Protection Agency
MNL: Multinomial Logit
NPL: National Priority List
RUM: Random Utility Model
WTP: Willingness to Pay

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welfare estimates are first compared between the two models and then with a number of market-based hedonic studies in the past. Implications of financing the cleanup, through increased property tax revenues are also investigated.

The survey-based conjoint choice approach is particularly suited to modeling housing choice. In this approach, respondents are asked to select the best alternative from all the available options in the choice set.[3] Each choice option in a choice set may consist of attributes of a differentiated product, such as housing. The appeal of the conjoint choice approach lies in its ability to let the analyst design choice options that include plausible site remediation scenarios along with structural and locational features of the homes that are located near the toxic site that is proposed to undergo remediation. This article employs the conjoint choice approach to survey homeowners and models housing choice as a discrete choice process under the RUM framework. One aim of the present study is to empirically investigate how effective the conjoint choice approach is in revealing homeowners' willingness to pay (WTP) for different levels of site remediation.

Like any choice-based study, the present study includes not only an elaborate and carefully made survey design, the choice experiment designed for the purpose—called orthogonal fractional factorial design in the statistical literature—has a special appeal, as it leads to efficient estimation of the utility parameters under the RUM framework. Unfortunately, econometric literature does not provide much guidance to judge the empirical validity of the results of the conjoint-based RUM estimation. To address the effectiveness of the survey-based approach, we present a hedonic price regression model to explore how welfare estimates obtained in the market-based hedonic model compare with those based on the survey-based RUM model. Comparing the two econometric methodologies is not only an important empirical exercise, it may also provide better understanding as to what needs to be done to bridge the gap between the welfare results from the survey-based and market-based approaches.

3. For a lucid exposition of conjoint choice approaches, readers may see Louviere et al. (2000). Interesting applications in environmental economics include Adamowicz et al. (1994, 1997), for modeling recreational demand, and Earnhart (2001), for modeling housing demand.

To achieve the above stated objectives, our application is based on market transactions of single-family homes by a sample of homeowners and a subsequent survey of the *same* sample of homeowners in Lake County, Illinois. Contaminated sediments in Waukegan Harbor, a Superfund site on the western shore of Lake Michigan, have been a major concern of the residents of the City of Waukegan and other nearby cities in Lake County. The site has been partially remediated, but a major condition for further investigations in cleanup is that the benefits are sufficient to justify the costs. This study builds on a recent exploratory study by Braden et al. (2004) and uses a more exhaustive dataset to shed light on the comparability of survey- and market-based methods with regards to the benefits to the residents of Waukegan, as well as on the potential for tax increment financing to fund cleanup.

In the next section we discuss issues relating to Superfund cleanup, with a particular focus on the Waukegan Harbor Superfund site. Section III discusses the data and presents the fractional factorial experimental design developed for use in the conjoint choice-based survey questionnaires. Section IV is devoted to theoretical specification of the RUM appropriate in the present context. The empirical results obtained from the RUM and the hedonic models are presented in Section V. Section VI focuses on computations of the welfare impacts, and comparison of those impacts between the RUM and the hedonic models, and between our study and some recent hedonic studies. Section VII concludes.

II. THE WAUKEGAN SUPERFUND SITE

The City of Waukegan is the governance center of Lake County and home to the only commercial harbor and harbor of refuge between Chicago, Illinois and Milwaukee, Wisconsin. A large recreational boat marina located in the harbor serves the greater region. The city itself is home to a large number of ethnic minority households. Hispanic households alone constitute 45% of the total (U.S. Census Bureau, 2001).

The city has three Superfund sites: the Johns-Manville site, the Outboard Marine Corporation site, and the Yeoman Creek Landfill site. The major pollution concerns resulting from these sites include severe asbestos contamination in the city's lakefront and polychlorinated biphenyl (PCB) contamination in the harbor (U.S. EPA, 2003). These pollutants were first identified by the Environmental Protection Agency (EPA) in 1975. This led to inclusion of the site in the National Priority List (NPL) under the Superfund cleanup law of 1980. The presence of high levels of contaminants in Waukegan Harbor generated tremendous concern at the international, national, and state levels. In 1981, the entire Waukegan Harbor area was jointly designated a "Great Lakes Area of Concern" (AOC) by the International Joint Commission (the binational organization responsible for protecting Great Lakes water quality), the EPA, and the Illinois Environmental Protection Agency (International Joint Commission, 2003).[4] Waukegan's remedial action plan identified several beneficial use impairments, including fish consumption restrictions, beach closings, and restrictions on dredging operations. During the early 1990s, $21 million was spent on initial cleanup. Although the Illinois EPA has detected improvements in the aquatic ecosystem, contamination in excess of current standards remains in the harbor. Further cleanup is estimated to cost an additional $21 million (Tsouderos, 2004), but it holds promise of removing the harbor from the NPL and AOC lists. Before those funds are invested, it is important to know the potential for an economic return.[5]

The damage that the sediment buildup has caused to the harbor, and consequently the surrounding communities, over the years is primarily in the form of the beneficial use impairments mentioned above, resulting from the accumulation of PCBs in the lake water and asbestos near the lakefront. However, the gradual deterioration of the harbor area has also made the region unattractive to prospective homeowners and business enterprises. During the two decades after Waukegan Harbor was added to the NPL and AOC lists, there has been a steady downturn in Waukegan's economy. Most of the heavy industries left the harbor area. High-income residents left the area only to be replaced by low-income immigrants, primarily of Hispanic origin, as neighborhoods near Waukegan became less desirable and unpleasant. The environmental stigma that is attached to the Waukegan Harbor has led to a steady decline in land and home values. Recent research suggests that the pattern that one sees in Waukegan is rather common for areas on the NPL list (Guntermann, 1995; Been, 1999; Dale et al., 1999). The Waukegan community is currently seeking to implement a city revitalization plan that includes transforming the city's worn industrialized downtown waterfront into an attractive place for residential, commercial, and recreational land uses (U.S. EPA, 2003).

III. DATA AND EXPERIMENTAL DESIGN

A. *Market Data*

Data on residential property transactions during 1996–2001 were provided by the Lake County Assessor's Office. A total of 47,100 transactions were recorded from 13 cities in Lake County, including Waukegan.[6] The variables in the market dataset include sale price of the house and three categories of attributes. The first category includes nine housing attributes: lot size, house size, house age, quality rating graded by assessors, number of bathrooms, availability of basement, number of fireplaces, availability of air conditioners, and availability of garage. It is expected that except for house age, all other attributes in this group will positively affect the house price. The second category has one accessibility feature measured as the distance of the house from the harbor computed by the Lake County GIS/Mapping Office. Many studies report substantial property value loss associated with proximity when a site near a residential area is declared potentially hazardous (e.g., Michaels and Smith, 1990; Kohlhase, 1991; Kiel, 1995). Because the locations close to Waukegan Harbor are less desirable compared to locations farther away from the harbor, we expect distance from the harbor to have a positive effect on house prices. The third category has one neighborhood feature, namely average public elementary school class size. This variable

4. Details available at http://www.ijc.org/php/publications/pdf/ID1500.pdf (accessed May 21, 2004).

5. For a detailed description of the status of the Waukegan Harbor AOC, see the final report (2003) prepared by the Northeast-Midwest Institute (2003), which is available from the authors upon request.

6. The other cities are Antioch, Avon, Ela, Freemont, Grant, Libertyville, Newport/Zion/Benton, Shields, Vernon, West Deerfield, Warren, and Wauconda. All of the assessment data are based on township jurisdiction, the boundaries of which may vary slightly from city borders in some cases.

TABLE 1
Description of Market Transaction Data

Variable Name	Variable Description	Mean/SD All (n = 954)	Waukegan (n = 514)	Outside Waukegan (n = 440)
adjpri	House price (2000 dollars)	255,305/624,604	128,109/41,891	403,895/896,542
lot	Lot size (acres)	0.28/0.38	0.23/0.19	0.35/0.52
size	House size (square feet)	2,526/1,694	2,082/1,352	3,044/1,896
grade	House condition (1 = fair…5 = excellent)	2.41/0.76	2.01/0.11	2.87/0.93
hage	House age (years)	34.69/24.53	46.51/21.98	20.71/19.56
baths	Number of bathrooms	1.65/0.82	1.51/0.74	1.82/0.88
bsmtdum	Basement (1 = present, 0 = absent)	0.81/0.39	0.84/0.37	0.77/0.42
fire	Number of fireplaces	0.43/0.62	0.31/0.49	0.56/0.73
acdum	Air conditioner (1 = present, 0 = absent)	0.59/0.41	0.38/0.49	0.84/0.37
atgardum	Attached garage (1 = present, 0 = absent)	0.29/0.45	0.25/0.44	0.33/0.47
harbmile	Distance to harbor (miles)	7.07/5.84	2.45/0.85	12.46/4.36
class	Average elementary school class size	24.16/1.65	24.48/0	23.79/2.39

Source: Lake County, Illinois, Assessment Office and GIS/Mapping Division.

proxies the school quality and is expected to influence the house price negatively. Data on class size by school district were obtained from the Illinois State Board of Education.

We selected a random sample of 2,500 transactions out of this population. Table 1 presents variable descriptions and descriptive statistics for the market variables for 954 homes from this sample. These 954 homes are relevant for the present study, since the homeowners of only these homes completed and returned survey booklets that were mailed to them for eliciting conjoint choice-based and socioeconomic information, to be discussed next. Summary statistics suggest that houses in Waukegan are, on average, smaller, less expensive, and in poorer condition compared to houses elsewhere in Lake County. The above market data were used to estimate the hedonic housing price function and subsequently the benefits associated with small and large changes in the distance from the harbor.

B. Survey Data

1. The Experimental Design for Conjoint Choice Data. The core of the survey asked respondents to make the choice between a hypothetical home and a "status quo" home. We use the market data along with the existing environmental conditions of the harbor as the "status quo" option in the conjoint choice questions for the homeowners surveyed. An illustrative choice scenario appears in Figure 1.

The set of attributes and their levels in each hypothetical option in a choice set are displayed in Table 2. With a view to reducing cognitive overload, the hypothetical choice option is benchmarked to the status quo, which is the current home.[7] Based on inputs from focus group participants, six features of the home and the harbor area were included in the hypothetical home in each choice set: lot size (*lot*), house size (*size*), elementary school class size (*class*), public areas near the harbor (*public*), extent of changes proposed in the harbor area pollution (*addpol*, *part*, *full*), and house price. Instead of presenting categorical levels of these features, as is done in most empirical studies, the values of the features in the hypothetical choice option are presented as percent higher or lower than the status quo.[8]

7. The use of a small number of choice options is generally believed to increase respondent efficiency in a hypothetical market. However, Hensher (2004), in an interesting recent study, points out that respondents' information processing capability is determined by both coping as well as relevancy. He shows that an efficient design strategy is the one that decides the number of alternative choices endogenously by varying the amount of information and letting the respondents decide the level of information they need to come up with their best responses.

8. Percentage differences in the attribute levels have been used in nonenvironmental economic applications (e.g., Hensher and Sullivan, 2003; Rigby and Burton, 2003), but have rarely, if ever been, used in environmental studies.

FIGURE 1
An Illustrative Choice Question

Home #1: Imagine your home modified to fit this description.

Features

	Lot size	House size	Average elementary school class size	Public or natural areas in Harbor Area	Harbor Area environmental condition	House price
Compared to your current home:	Smaller by 15%	Smaller by 15%	Smaller by 2 students	Smaller by 20%	Additional pollution	Less expensive by 10%

Which do you prefer?

- ❑ The home described above
- ❑ My current home

Each attribute is in four levels. A complete factorial design for six attributes, each at four levels has 4^6 (= 4096) treatment combinations. There are six main effects, each with three degrees of freedom, implying 18 parameters to be estimated for a main-effects design. To estimate these parameters independently, an orthogonal main-effects design must be a fractional factorial design with at least 2^m treatment combinations, where m is such that $2^m > 18$. Thus the smallest regular fraction in which the main effects are independent contains a subset of 32 treatment combinations.

In addition to the main effects, to allow for the interaction effects of income with attributes and of house price with attributes to be estimated independently, we require a fractional factorial design that must be able to independently estimate 15 more parameters.[9,10] To estimate all 33 parameters $(18 + 15)$, the minimum design necessary is a set of $2^5 = 64$ treatment combinations. However, in order to avoid the possibility of bias in the main effects through *unobserved* two-way interactions between attributes, we create a fold-over design of another set of 64 treatment combinations by using the annual house payment variable, to be discussed in Section V, as the blocking variable (Louviere, 1988).[11] This makes a total of 128 treatment combinations, or 128 choice sets.[12]

Presenting all 128 choice sets, each with two options, would be a heavy burden on the respondents, and it may impair the respondents' ability to make rational choices. It is thus common in conjoint choice-based approaches to randomly divide the full choice set into several subsets of choices (Adamowicz et al., 1994, 1997). In the present study, we randomly divided the full choice set into eight groups of 16 choice sets each. The survey respondents were consequently randomly assigned to eight groups and every homeowner within a group was assigned the same subset of 16 choice sets. Homeowners across groups received a different subset of 16 choice sets.

9. Adamowicz (1994, 1997) and Earnhart (2001) use orthogonal design that can independently estimate the main effects of the model, but sacrifice, perhaps without much loss, the possible effects of second- and higher-order interactions.

10. In a RUM framework, respondents' socioeconomic characteristics, such a income, race, family size, etc., cancel out in the estimating equation. To resolve this problem, it is common in the RUM estimation to have the socioeconomic variables interacted with choice attributes. In the case of income, however, a variable termed composite good, defined as house price minus income, is commonly used in RUM estimation to handle this problem. Thus an interaction of composite good with choice attributes implies interactions of attributes with both income and price.

11. We are grateful to Jordan Louviere for his help in developing the experimental design.

12. Due to concerns about the effectiveness of the survey elicitation, and to reduce the total number of choice sets per respondent, we limited our design to six attributes. The details of how the design is generated are available from the authors on request.

2. *Other Survey Data.* In addition to the conjoint choice questions, the survey provided a description and a map of the harbor area, an overview of the harbor contamination, effects on beneficial uses of the harbor, past remediation, and remaining problems. Recipients were also asked to report house age, type (single family, townhouse, or condominium apartment), number of rooms, house size, lot size, and estimated average number of students per class in their neighborhood elementary school. This set of information was primarily intended to check comparability with the assessment data described in Table 1. The respondents were also asked to express opinions about the harbor area at the time of their home purchase, including whether it was attractive, improved the quality of life, and was environmentally safe. Details on households' socioeconomic information, such as income, number of children, and primary language spoken in the household, were obtained through a mail survey.

From the property transactions sample, a survey booklet was mailed to 2,339 households in November 2002. The survey elicited 954 responses.[13,14] For the conjoint choice part of the survey, this implies a total of 15,264 (= 954×16) choice opportunities. There were 817 unusable observations, leaving 14,447 usable responses.[15,16] Details of the survey-based data are presented in Table 3, along with descriptive statistics. The conjoint choice-based information and socioeconomic information, namely income and language spoken, are the only ones that are used in the RUM estimation.

IV. THEORETICAL MODEL

The RUM attempts to model the residential choice of a household under a discrete-choice framework. It has been used frequently to value housing attributes (e.g., Nechyba and Strauss, 1998), although applications to the environmental attributes of housing are infrequent (e.g., Smith and Desvouges, 1986; Chattopadhyay, 2000; Earnhart, 2001).

The theory and assumptions underlying the RUM are well known (e.g., Ben-Akiva and Lerman, 1985; Morey, 1999; Louviere et al., 2000). Given a finite set of alternative residential units characterized by distinct attributes, the RUM makes a probability statement that the unit that is chosen brings the highest utility to the consumer. The model specifies a stochastic indirect utility function of the form

$$(1) \quad U_j = V(X_j, \mathbf{z}_j; \beta) + \varepsilon_j, \quad j = 1, 2, \ldots, J,$$

where V is the deterministic part of the utility, $\mathbf{z}_j$ is a vector of attributes of dwelling choice option j, β is a vector of unknown parameters characterizing the utility function, and ε_j is the unobserved portion of the utility associated with the dwelling choice option j. Finally, X_j is household's consumption of a numeraire non-housing good, defined as $X_j = Y - P_j$, where Y is household income and P_j is the price paid for the dwelling choice option j. The probability that a household makes choice j out of a set of choice options J is given by

$$(2) \quad P_j = P(U_j > U_{j'}) \quad \forall j' \neq j = 1, 2, \ldots, J.$$

If ε is assumed to follow an i.i.d. extreme value type I distribution, then McFadden (1974, 1978) has shown that Equation (2) translates into the multinomial/conditional logit model (MNL/CLM) of the following form:[17]

13. The survey was developed and administered in collaboration with the Survey Research Laboratory of the University of Illinois and with input from a focus group of Waukegan area residents, the results of a pretest mailing of 50 surveys, and feedback from academic experts in survey design and implementation. Respondents received a \$2 incentive payment. After two follow-up mailings, the second including a new copy of the survey, the response rate was 41%.

14. Difference-in-mean tests between the full sample and the respondent sample were conducted for house price and each of the structural and locational variables presented in Table 1. The tests turned out to be insignificant for all the variables at the 5% level, signifying that nonresponse bias may not be a problem.

15. In the useable sample, each of the eight groups of 16 choice sets mentioned before has representation. However, some groups have greater representations than others. This might affect the orthogonality of the design and independent estimation of the pure effects.

16. Because there are 16 choice options per respondent, there are repeated observations for each household, which may be correlated. Following previous literature on choice-based valuation (Adamowicz et al., 1994, 1997; Earnhart, 2001), we did not control for the correlated responses to minimize potential bias.

17. The difference between the MNL and the CLM is that in the latter case, the values of the choice characteristics vary across choices, while the parameters are common across the choices. Here, the likelihood of a choice decision is calculated *conditional* on the nature of the choices that define the choice sets. In the former case, however, the values of the variables are common across choices for the same person, but the parameters vary across choices.

TABLE 2
Conjoint Choice Attributes and Levels

Attribute (*Name*)	Levels	Notes
Lot size (*lot*)	15% smaller	In assessment data, this variable is measured in acreage of the lot.
	No change	
	15% larger	
	25% larger	
House size (*size*)	15% smaller	In assessment data, square feet of living area is the metric used.
	No change	
	15% larger	
	25% larger	
Average class size in the neighborhood public elementary school (*class*)	Smaller by two students	The county average is 23 students.
	No change	
	Larger by two students	
	Larger by four students	
Area devoted to nature, recreation, and boating in the harbor area (*public*)	20% (10 acres) less	This includes beaches, parks, recreational fields, natural areas and preserves, fishing areas, and boat slips in the harbor area.
	No change	
	50% (20 acres) larger	
	100% (50 acres) larger	
Harbor area environmental condition (*addpol*, *part*, *full*)	Additional pollution	"Additional pollution" implies further deterioration of the current condition.
	No change	"No change" refers to area of concern (AOC): no additional clean-up, pollution remains in the harbor and the nearby land.
	Partial cleanup	"Partial clean-up" refers to area of recovery AOR: some additional clean-up in the boat harbor and nearby land.
	Full cleanup	"Full clean-up" refers to delisted: extensive clean-up throughout the harbor area and environmental goals are met.
House payment	10% less expensive	In assessment data, this equals the sale price at the time of the most recent purchase.
	No change	
	10% more expensive	
	30% more expensive	

$$P_j = \frac{\exp(\lambda V_j)}{\sum_{j'=1}^{J} \exp(\lambda V_{j'})}, \tag{3}$$

where J is the number of dwelling choice options, P_j is the probability that a household chooses the jth dwelling, and λ is the scale factor typically assumed to be one (Louviere et al., 2000). The parameter vector β in the expression V_j in Equation (3) can be estimated by maximum likelihood.

In the present study, there are two alternatives in the choice set: the status quo home and the hypothetical home. In addition to reducing the cognitive burden on respondents, the binary option framework on which the present study is based has two econometric advantages. First, it eliminates the issues of

TABLE 3
Descriptive Statistics for Stated Preference Data[a]

Variable/Questions/Statements	All (n = 14,447)	Waukegan (n = 7,771)	Outside Waukegan (n = 6,676)
House lot size (acres)			
Stated-actual[b,c]	0.31	0.27	0.37
Hypothetical choices[d]	0.28	0.23	0.34
Degree of importance[e,f]	"Somewhat": 55.5%	"Somewhat": 55.8%	"Somewhat": 55.1%
House living area (1000 ft^2)			
Stated-actual[b,c]	1.73	1.43	2.08
Hypothetical choices[d]	2.59	2.15	3.11
Degree of importance[e,f]	"Somewhat": 59.5%	"Somewhat": 57.4%	"Somewhat": 61.9%
House age (years)[c]	32.74	41.78	22.20
House price ($1,000, year 2000)			
Stated-actual[b,c]	n/a	n/a	n/a
Hypothetical choices[d]	239.60	119.98	378.96
Degree of importance[e,f]	"Very": 79.5%	"Very": 78.9%	"Very": 80.1%
Class size by district (students/class)			
Stated-actual[b,c]	23.00	23.00	23.00
Hypothetical choices[d]	24.28	24.64	23.85
Degree of importance[e,f]	"Very": 56.9%	"Very": 51.4%	"Very": 63.3%
Importance of harbor pollution[e,f]	"Somewhat": 38.9%	"Somewhat": 41.9%	"Not at all": 42.5%
Single-family detached house[f]	87.6%	89.5%	85.4%
Language used[f]	English: 80.5%	English: 70.0%	English: 92.7%
Year home bought[f]	1999: 28.2%	1999: 34.3%	1999: 21.1%
Number of rooms[c]	7.9	6.9	9.2
Household size (no. of people)[g]	3.2	3.3	2.9
Have any children?[f]	Yes: 54.3%	Yes: 56.0%	Yes: 52.3%
Household size, given has children[g]	4.0	4.2	3.7
Household 2000 income ($1,000)[c]	89.4	63.6	119.41
Mode of house payments[f]	Monthly: 91.3%	Monthly: 92.3%	Monthly: 90.2%
Harbor is attractive[f,g]	No opinion: 36.0%	Moderately agree: 30.4%	No opinion: 51.1%
Harbor enhances quality of life[f,g]	No opinion: 41.3%	No opinion: 30.0%	No opinion: 54.8%
Harbor is important to economy[f,g]	No opinion: 41.0%	Moderately agree: 31.2%	No opinion: 54.6%
Harbor is safe[f,g]	No opinion: 41.9%	No opinion: 29.6%	No opinion: 56.2%
Harbor is going to be redeveloped[f,g]	No opinion: 50.7%	No opinion: 36.6%	No opinion: 67.1%

[a]Sample means are numbers and are for continuous variables, modal responses are in percentages and are for categorical variables.
[b]As answered by respondent on the questionnaire.
[c]We asked question in categorical format. We then took the midpoints of the categories and calculated the mean of reported values.
[d]We took into account the hypothetical choices made by respondents with reference to their current homes, converted them to absolute values using market data as the benchmark, then calculated the mean.
[e]Categories asked were "Not at all important," "Somewhat important," and "Very important."
[f]Modal response.
[g]Categories asked were "Strongly agree," "Moderately agree," "No opinion," "Moderately disagree," and "Strongly disagree."

independence of irrelevant alternatives (IIA). Second, the inclusion of the status quo option reduces the possibility of an upward bias in the welfare estimates that often creeps in when the status quo option is not presented to the respondent in the choice process (Boyle et al., 2001).

Welfare measures from the above probabilistic choice model are based on the expected utility relationship. For preferences that yield a constant marginal utility of income, expected compensating variation (CV) has a closed-form expression (Bockstael et al., 1991; Hanemann, 1999).[18] For instance, for homeowner i facing a choice set $j = 1, 2, \ldots, J$, a measure of expected CV is given by

$$E(CV) = \frac{1}{\gamma}\Big[\ln \sum_{j=1}^{J} \exp(V_{j1}) - \ln \sum_{j=1}^{J} \exp(V_{j0})\Big], \tag{4}$$

where γ denotes the constant marginal utility of income, V_{j0} denotes the deterministic utility at the initial state, and V_{j1} is the utility at the final state. Econometric estimation of the expected welfare in Equation (4) involves (i) maximum likelihood estimation of the parameters of the deterministic part of the utility function V, including the parameter γ; and (ii) computation of the deterministic utility V for each choice option (current home or proposed home) and with current (=0, for example, "no change") and proposed (=1, for example, "full cleanup") environmental scenarios.

V. APPLICATION

A. Specification of the RUM

There are certain key issues that must be addressed before specifying the empirical model. First, as discussed above and presented in the choice set example in Figure 1, the attribute levels of the hypothetical home in a choice set are benchmarked to the attributes of the status quo home. Thus, prior to estimation, we transformed the relative attribute levels of the hypothetical homes into their corresponding absolute values. Second, the two choice alternatives in each choice set, namely the status quo home and the hypothetical home, may be perceived differently by respondents, perhaps due to familiarity. To capture the average of this unobserved effect, we introduce an alternative specific constant (*asc*) as a dummy that takes the value one for the hypothetical home and zero for the baseline home.

Third, all categorical attributes (including environmental attributes) are effects coded. Effects coding of categorical variables is common in statistical designs of experiment literature. Unlike (0, 1) dummy coding, effects coding involves two levels (−1, 1), with −1 representing the base level. Effects coding has several important estimation properties. One is that it orthogonalizes the effects of attributes with the *asc*, whereas dummy coding confounds it.[19]

Finally, we converted all dollar values into year 2000 (fourth quarter) purchasing power. In particular, mortgage payments are annualized to year 2000 present value based on a 30-year fixed mortgage with the prevailing mortgage interest rate of 8.05%. We use the Federal National Mortgage Association's Conventional Mortgage House Price Index (CMHPI) to convert home sale prices.

To facilitate exact welfare measurement, we specify an indirect utility function that yields constant marginal utility of income. The dependent variable is the probability of choosing a particular house. The main-effects variables are the choice-specific structural and community attributes. The model also includes socioeconomic variables through interactions with the choice-specific attributes. The resulting model follows:

$$\begin{aligned} V = {} & \beta_0 asc + \beta_1 \ln(lot) + \beta_2 \ln(size) \\ & + \beta_3 \ln(class) + \beta_4 \ln(public) \\ & + \beta_5 cgood + \beta_{6a} addpol + \beta_{6b} part \\ & + \beta_{6c} full + (\beta_7 \ln(lot) + \beta_8 \ln(size) \\ & + \beta_9 \ln(class) + \beta_{10} \ln(public) \\ & + \beta_{11} cgood + \beta_{12a} addpol \\ & + \beta_{12b} part + \beta_{12c} full) waudum \\ & + (\beta_{13} \ln(lot) + \beta_{14} \ln(size) \\ & + \beta_{15} \ln(class) + \beta_{16} public \\ & + \beta_{17} cgood + \beta_{18a} addpol \\ & + \beta_{18b} part + \beta_{18c} full) lang \\ & + (\beta_{19} \ln(lot) + \beta_{20} \ln(size) \\ & + \beta_{21} \ln(class) + \beta_{22} \ln(public) \\ & + \beta_{23} cgood + \beta_{24a} addpol \\ & + \beta_{24b} part + \beta_{24c} full) midinc \\ & + (\beta_{25} \ln(lot) + \beta_{26} \ln(size) \\ & + \beta_{27} \ln(class) + \beta_{28} \ln(public) \\ & + \beta_{29} cgood + \beta_{30a} addpol \\ & + \beta_{30b} part + \beta_{30c} full) highinc. \end{aligned} \tag{5}$$

18. For preference structures that yield nonconstant marginal utility of income, no closed-form solution to expected CV exists (Hanemann, 1999).

19. For an explanation of the properties of effects coding, readers should refer to Adamowicz et al. (1994).

The nonenvironmental attributes are the alternative-specific constant (*asc* = 1 for hypothetical home, = 0 for status quo home), lot size (*lot*, acres), house size (*size*, 1000 ft^2), and public elementary school class size (*class*, average number of students in public elementary school classes by community); environmental attributes are the area in public parks and natural areas near the harbor (*public*, acres); and the four effects-coded attributes are more pollution (if yes, *addpol* = 1; if not *addpol* = 0), partial cleanup (if yes, *part* = 1; if not = 0), full cleanup (if yes, *full* = 1, if not = 0), with no change (*addpol* = −1, *full* = −1) as the reference group. The variable *cgood* is the composite numeraire good measured as the difference between annual house payment and income. Income figures are self-reported in categories and house payment is the approximate annualized mortgage payment in year 2000 dollars, as discussed above. Except for the effects-coded variables and the variable *cgood*, all other variables were converted to natural logarithms (ln). The variable *cgood* was not transformed, to ensure a closed-form solution for expected compensating variation.

The socioeconomic variables included as interactions with the attributes are the language used in the household (*lang*, English or other than English, effects-coded); the three effects-coded income categories, namely high income group (*highinc*, = 1 if income > \$110,000), medium income group (*medinc*, = 1 if income between \$50,000 and \$110,000), and low-income (income < \$50,000), with low income being the reference category; and, finally, an effects-coded variable to distinguish Waukegan residents from those living outside the city (if resident of Waukegan, *waudum* = 1; if not *waudum* = −1).[20] In the hedonic analysis, this variable is dummy-coded, although with the same name. In short, the variables that are effects-coded in the RUM analysis of the present study are the environmental attributes (*addpol*, *part*, and *full*), the socioeconomic variables (*lang*, *medinc*, and *highinc*), and the location variable *waudum*.

We included *waudum* specifically to capture the effects of residential segregation on locational choice. Compared to Lake County and the State of Illinois, Waukegan has an unusually large population of Hispanic and other migrants and lower income people (Northeast-Midwest Institute, 2003). Also, as the summary statistics in Table 1 indicate, the City of Waukegan appears to be distinctly inferior to other cities in Lake County with respect to the quality of housing.

B. RUM Estimation and Results

The results of the conditional logit RUM estimation appear in Table 4. Out of a total of 41 coefficients, 23 are significant at the 10% level or better. Overall model performance measured by pseudo-R^2 of 0.35 indicates a very good fit.[21] The negative and significant coefficient on *asc* reflects, all else being equal, that homeowners are averse to the hypothetical homes for reasons that are not separately observed in the present study. Because all the attributes are interacted with *waudum*, *lang*, *midinc*, and *highinc*, interpretation of the overall impact of the attributes is not straight-forward. Generally, additional pollution is disliked, whereas full cleanup is more preferred than partial cleanup.

The interaction terms provide insights into the distribution of preferences. For instance, the positive and significant coefficients on *addpol*waudum*, *part*waudum*, and *full* waudum* indicate that residents of Waukegan dislike additional pollution less, but prefer to have partial or full cleanup more than the residents elsewhere in Lake County. The insignificant coefficient on *addpol*lang* indicates that English-speaking and non-English-speaking residents are no different in their dislike for additional pollution. The positive and significant coefficients on *part*lang* and *full*lang* indicate that English-speaking residents prefer to have partial or full cleanup more compared to non-English-speaking residents. In addition, English-speaking residents prefer to have full cleanup more than partial cleanup.

The insignificant coefficients on *addpol*midinc* and *part*midinc* indicate that

20. The main advantage of introducing separate income categories is that such a specification produces the same marginal utility of income within income categories, but different marginal utilities of income across categories. Although a closed-form expression for welfare change does not exist for preference structures that yield nonconstant marginal utility of income, a closed-form expression can be derived separately for each different income category, with the restriction that the marginal utility is constant within each category.

21. According to Louviere et al. (2000), a pseudo-R^2 between 0.2 and 0.4 is equivalent to an R^2 of 0.7 to 0.9 in regular ordinary least squares (OLS) estimation.

TABLE 4
RUM Estimation Results

Variable	Coefficient	S.E.
asc	−2.9901***	0.0559
ln(*lot*)	1.5855***	0.3215
ln(*size*)	3.4319***	0.3386
ln(*class*)	−1.0956**	0.5205
ln(*public*)	0.3569***	0.1265
cgood	0.0981***	0.0246
addpol	−0.5187***	0.0707
part	0.1238**	0.0531
full	0.2940***	0.0543
ln(*lot*)**waudum*	0.3687**	0.1804
ln(*size*)**waudum*	0.1487	0.1854
ln(*class*)**waudum*	0.2518	0.3009
ln(*public*)**waudum*	0.9207	0.0703
*cgood*waudum*	0.1239***	0.0124
*addpol*waudum*	0.0758**	0.0384
*part*waudum*	0.1082***	0.0280
*full*waudum*	0.2322***	0.0280
ln(*lot*)**lang*	0.1825	0.2545
ln(*size*)**lang*	1.1966***	0.2615
ln(*class*)**lang*	−2.2493***	0.4223
ln(*public*)**lang*	−0.1344	0.1000
*cgood*lang*	0.1085***	0.0244
*addpol*lang*	0.0180	0.0527
*part*lang*	0.1489***	0.0407
*full*lang*	0.2980***	0.0424
ln(*lot*)**midinc*	0.2950	0.1937
ln(*size*)**midinc*	0.2183	0.1975
ln(*class*)**midinc*	−0.1944	0.3249
ln(*public*)**midinc*	−0.0087	0.0753
*cgood*midinc*	−0.0411**	0.0150
*addpol*midinc*	−0.0615	0.0404
*part*midinc*	0.0220	0.0312
*full*midinc*	0.0758**	0.0301
ln(*lot*)**highinc*	0.4147	0.2539
ln(*size*)**highinc*	0.4060	0.2591
ln(*class*)**highinc*	−0.3758	0.4126
ln(*public*)**highinc*	−0.0970	0.0988
*cgood*highinc*	−0.0438***	0.0154
*addpol*highinc*	−0.0747	0.0543
*part*highinc*	0.0416	0.0395
*full*highinc*	0.1001**	0.0394
Log-likelihood for the model	−11,847.59	Adjusted pseudo-R^2 0.3488
Sample size	14,447	

Significant at the ***0.01 level, **0.05 level, *0.10 level.

medium-income residents are no different from others in their dislike for additional pollution and preference for partial cleanup. However, the significant coefficient on *full*midinc* indicates medium-income residents prefer full cleanup more than other income categories, on average. Similarly, the significant coefficient for the interaction variable *full*highinc* indicates that high-income residents prefer full cleanup more than other categories, while the insignificant coefficients on *addpol*highinc* and *part*highinc* indicate that high-income residents are no different from others with respect to their dislike for additional pollution and their preference for partial cleanup. In general, preferences are similar across income categories with respect to partial cleanup, but they vary significantly across income categories with respect to additional pollution and full cleanup. Finally, the significant and negative coefficients on *cgood*midinc* and *cgood*highinc* indicate that marginal utility of income is significantly lower for the medium- and high-income groups compared to the low-income group.

C. *Specification of the Hedonic Model*

We estimate a standard, first-stage hedonic model based on market data, presented in Table 1. We assume that the housing market is in short-run competitive equilibrium and the hedonic housing price function is the locus of the points connecting buyers' bid and sellers' offer curves (Rosen, 1974; Quigley, 1982; Freeman, 2003). We specify the following nonlinear hedonic price function:[22]

$$
\begin{aligned}
(6)\quad \ln(adjpri) &= \delta_0 + \delta_{99}year99 \\
&\quad + \delta_{00}year00 + \delta_{01}year01 \\
&\quad + \delta_1\ln(lot) + \delta_2\ln(size) \\
&\quad + \delta_3\ln(class) + \delta_4\ln(hage) \\
&\quad + \delta_5 grade + \delta_6 bsmt + \delta_7 baths \\
&\quad + \delta_8 acdum + \delta_9 fire + \delta_{10} atgardum \\
&\quad + \delta_{11}\ln(harbmile) + [\delta_{12}\ln(lot) \\
&\quad + \delta_{13}\ln(size) + \delta_{14}\ln(class) \\
&\quad + \delta_{15}\ln(hage) + \delta_{16} grade + \delta_{17} bsmt \\
&\quad + \delta_{18} baths + \delta_{19} acdum \\
&\quad + \delta_{20} fire + \delta_{21} atgardum \\
&\quad + \delta_{22}\ln(harbmile)]waudum
\end{aligned}
$$

22. The number of noninteracted explanatory variables in the present hedonic regression is smaller compared to what one often finds in other studies, such as in Palmquist (1984), Zabel and Kiel (2000), and Chattopadhyay (2002). However, unlike the cited studies, which cover one or more metropolitan centers, the present study is limited to a number of suburban towns and, as a result, we did not find more factors that could have influenced house prices.

The variables are defined in Table 1. The year dummies are to capture the year effects for the properties sold in the years 1999, 2000, and 2001, with the property transactions that took place on or before 1998 as the reference period.[23] There are three reasons to choose the above specification. First, a "no arbitrage" restriction requires that housing price function be nonlinear.[24] Second, we hypothesize that market segmentation exists between Waukegan and other cities in Lake County. A test for market segmentation requires that the dummy variable *waudum* (defined waudum = 1 if the property is in Waukegan, = 0 if outside Waukegan) be interacted with the other variables. Finally, to make the hedonic model comparable to the RUM, the variables and their interaction terms in Equation (6) are as similar to Equation (5) as the data and the theory permit.[25] For example, the common variables in the two models—namely lot size (*lot*), house size (*size*), and elementary school class size (*class*)—and other variables that do not include a zero or do not take only a few discrete numbers are all converted to natural logarithms.

D. *Hedonic Estimation and Results*

The results of the hedonic price regression appear in Table 5. An R^2 of 0.65 suggests that the model explains substantial variation. Out of a total of 11 noninteracted variables, except for the distance variable ln(*harbmile*) and the garage dummy *attgardum*, all coefficients are significant at the 10% level or better. Except for the variables ln(*hage*), ln(*acdum*), and ln(*harbmile*), all other variables interacted with *waudum* are generally insignificant.

TABLE 5
Hedonic Estimation Results

Explanatory Variables	Estimates	S.E.[a]
year99	−0.1126**	0.0549
year00	0.0399	0.0673
year01	0.0171	0.0543
ln(*lot*)	0.0764***	0.0262
ln(*size*)	0.3042***	0.0645
ln(*class*)	−1.0021***	0.1868
ln(*hage*)	−0.1090**	0.0460
grade	0.0913**	0.0418
bsmt	0.2526***	0.0588
baths	0.0633*	0.0326
acdum	0.2141***	0.0538
fire	0.1519***	0.0417
atgardum	0.0878	0.0625
ln(*harbmile*)	−0.0812	0.0670
ln(*lot*)**waudum*	−0.0014	0.0403
ln(*size*)**waudum*	−0.0494	0.0818
ln(*class*)**waudum*	−0.1838	0.2245
ln(*hage*)**waudum*	0.1617***	0.0584
*grade***waudum*	−0.0335	0.1247
*bsmt***waudum*	−0.0492	0.0698
*baths***waudum*	0.0078	0.0402
*acdum***waudum*	−0.1862***	0.0584
*fire***waudum*	−0.0575	0.0553
*atgardum***waudum*	−0.0053	0.0690
ln(*harbmile*)**waudum*	0.1931**	0.0816
Constant	13.0006***	0.8875
R^2	0.6469	
Sample size	954	

Significant at the ***0.01 level, **0.05 level, *0.10 level.

[a]Standard errors are robust standard errors.

A negative and significant coefficient on the *year99* dummy implies that the equilibrium prices of properties sold in the year 1999 are, on average, lower at the 5% level than those sold before 1999—the reference period. Prices in the other years are not significantly different from those in the reference period.[26] An *F*-test based on the estimated model strongly weighs against "no market segmentation" with a *P*-value close to zero.

Because all of the main-effects variables are also interacted with *waudum*, the direction and magnitude of the effects on house price are

23. The total number of observations are 179, 262, 285, and 228 for the years 2001, 2000, 1999, and prior to 1999, respectively. The year dummies were designed to bring out the effects, if any, on the local housing market associated with the economic boom, bust, and recession that took place at the national level during those years.

24. For a differentiated product, such as housing, this implies product attributes are bundled and cannot be costlessly repackaged in the short run. For example, having two 200 square foot rooms is not the same as having one 400 square foot room. Absence of repackaging possibilities makes the housing price function nonlinear in product attributes. This in turn ensures that marginal prices of attributes depend on the level of attributes. For an elaborate explanation of Rosen's (1974) hedonic theory, see Palmquist (1991).

25. Equations (5) and (6) are clearly nonnested models and, as such, the scope of comparison between the models is limited.

26. Separate tests for equality of coefficients suggests that prices for the years 2000 and 2001 are significantly different from the prices for the year 1999, on average. However, the year effect on house price for the year 2000 is not significantly different from that for the year 2001.

not immediately apparent. The significant coefficients on the interacted variables house age (*hage*), air conditioner (*acdum*), and ln(*harbmile*) suggest that Waukegan and non-Waukegan housing markets affect house price differently with respect to these variables. Similarly, the coefficients on the rest of the interacted variables are insignificant, implying that Waukegan and non-Waukegan housing markets respond similarly to changes in these variables.

A significant coefficient on the interaction variable ln(*harbmile*)**waudum* suggests that house price increases for Waukegan homes that are farther away from the polluted Waukegan Harbor. However, the insignificant main-effects coefficient on ln(*harbmile*) suggests that, all else being equal, an increase in the distance of the homes from the harbor does not increase house price significantly for non-Waukegan homes that are already farther away from the polluted harbor. These findings are quite plausible, since many studies have shown that the proximity effect vanishes after a certain distance from a polluted site. Kohlhase (1991) finds that the distance gradient for a hazardous waste site can extend up to six miles from the site.[27]

E. Comparison of Marginal WTP

The assumption that the housing market is in short-run equilibrium ensures that the marginal price of each attribute obtained from the estimated housing price regression of Equation (6) equals the marginal WTP for that attribute. We compute the equilibrium marginal prices for the three variables that appear in both the RUM specification of Equation (5) and the hedonic specification of Equation (6): *lot*, *size*, and *class*. The expression for marginal WTP for these variables from Equation (6) is

$$(7)\quad \text{marginal price} = \text{marginal WTP} = \delta_i \frac{adjpri}{z}, \quad i = 1, 2, 3,$$

where z is the relevant attribute level. The expression for marginal WTP for the three aforementioned variables in the RUM specification is

TABLE 6
Comparison of Marginal WTP for Common Attributes

	WTP			
	Hedonic		RUM	
Variable	Mean	S.D.	Mean	S.D.
lot	164,133	489,127	106,313	271,553
size	22.21	53.09	13.07	10.56
class	−11,313	24,933	−816	821
Sample size	954		14,447	

$$(8)\quad \text{marginal WTP} = \frac{\partial V/\partial z}{\partial V/\partial(cgood)}.$$

The mean and the standard deviation of the marginal WTP figures based on Equations (7) and (8) appear in Table 6.[28] For two of the common attributes—*lot* and *size*—the two models produce similar estimates of mean marginal WTP. For instance, in the case of *size*, all else being equal, households' average WTP for an additional square footage of house size is \$22.21 in the hedonic approach and \$13.07 in the RUM approach. The estimates for *class*, however, differ by two orders of magnitude—the average WTP for a one-student reduction is \$11,313 in the hedonic approach and \$816 in the RUM approach, all else being equal.

One possible reason for the large difference in the marginal WTP for class size is an unobserved association between public school quality and other locational public amenities, such as better roads and sidewalks and safer neighborhoods. In the hedonic model, the variable

27. Because Waukegan Harbor is located in the City of Waukegan, the city is closer to the Superfund sites. All the other cities in the sample are farther away from the harbor compared to Waukegan. Waukegan's city limit ranges from three to five miles from the harbor. Some of the homes in other cities included in the sample are as far as 20 miles away.

28. It is common in hedonic literature to explore a number of functional forms for hedonic specifications (Cropper et al., 1988; Chattopadhyay, 2002). We tried the semilog form, but found the double-log functional form performs better than the semilog form with respect to R^2 and with respect to the number of significant variables. However, both forms produce almost similar mean and median marginal WTP for the three attributes. In the case of the RUM specification, we estimated the model without transforming any variables to natural logarithms. The natural log model in Equation (7) was found to outperform on the basis of both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). Moreover, mean and median marginal WTP for the common variables, and the mean and median expected compensating variations for the environmental variables, to be discussed in the next section, were found to be unaffected by the changes in specification. All the different estimation results are available from the authors on request.

TABLE 7
Aggregate WTP of Residential Property Owners in the RUM Approach[a]

Community/Environmental Condition	Mean Household WTP ($/Household/year)[b]	Present Value ($/Household)[c]	Number of Households	Community Aggregate WTP (million $)
Waukegan				
Full cleanup	$3,046	$34,130.07	15,697	$534.74
Partial cleanup	($3,013, $3,079)	$15,854.91		$248.87
Added pollution	$1,415	−$25,849.66		−$405.76
	($1,399, $1,431)			
	−$2,307			
	(−$2,332, −$2,282)			
Non-Waukegan				
Full cleanup	$7,001	$78,445.38	152,604	$11,971.08
Partial cleanup	($6,975, $7,061)	$36,158.16		$5,517.88
Added pollution	$3,227	$126,279.03		−$19,270.68
	($3,97, $3,257)			
	−$11,270			
	(−$11,387, −$11,153)			

[a]WTP values are in year 2000 dollars.
[b]Numbers within parentheses are 95% confidence bounds for mean WTP.
[c]Present value is calculated by assuming the year 2000 average interest rate (8.05%) for a 30-year fixed-rate mortgage.

class may capture the effects of these unobserved amenities, resulting in larger estimates of marginal WTP. The greater specificity of the conjoint choice exercise may reduce the potential for confounding effects. The estimates in the survey-based RUM model are consistently lower than those from the market-based hedonic model. Thus it is also possible that the survey produced more conservative estimates because respondents were not free to vary all aspects of their home choice, especially location, while the choices evident in the transactions data are not similarly constrained.

VI. WELFARE IMPLICATIONS FOR HARBOR CLEANUP

A. *Survey-Based RUM Estimates*

In the case of two-choice options, the expected compensating variation presented in Equation (4) yields the following expression (Bockstael et al., 1991, p. 262):

$$WTP = \frac{1}{\gamma}\ln\left[\frac{\exp(V_{01}) + \exp(V_{11})}{\exp(V_{00}) + \exp(V_{11})}\right], \tag{9}$$

where γ is the constant marginal utility of income. In the present context, however, γ differs across income groups. The term V_{00} is the household utility associated with the current home and the status quo environmental quality (no change condition), V_{01} is the household utility with the current home and the hypothetical environmental quality (full cleanup, or partial cleanup, or added pollution), and V_{11} is the household utility with the hypothetical home and the hypothetical environmental quality.

Table 7 presents the mean annual WTP for each of the three proposed changes in the environmental conditions together with the 95% confidence bounds.[29] For example, an average Waukegan homeowner is willing to pay $3,046 and an average non-Waukegan homeowner is willing to pay $7,001 as an annual house

29. Because we are using unweighted averages, there could be biases in the estimates if the WTP distributions deviate too much from a symmetric normal distribution. Since, for a normal distribution, mean, median, and mode coincide, we checked the extent of departure from normality by computing the mean, median, and mode of the annual WTP distribution in the sample. For the Waukegan sample, these values are (i) "full cleanup" (mean = $3,046, median = $3,102, mode = $2,497); (ii) "partial cleanup" (mean = $1,415, median = $1,515, mode = $2,124); and (iii) "additional pollution" (mean = −$2,307, median = −$2,363, mode = −$1,389). For the non-Waukegan sample, these values are (i) "full cleanup" (mean = $7,001, median = $7,598, mode = $7,503); (ii) "partial cleanup" (mean = $3,227, median = $3,303, mode = $3,273); and (iii) "additional pollution" (mean = −$11,270, median = −$12,889, mode = −$13,862). The above results suggest that the degree of departure from normality is minimal in the WTP distribution.

payment for full cleanup of the harbor. The third column reports the present values of the mean annual WTP for each scenario. These are calculated as the value of a 30-year mortgage that would be amortized by the annual payment equal to the WTP, using the average interest rate of 8.05%, as before. The present values are aggregated to the community level in the last column. All of the figures are reported separately for the Waukegan and non-Waukegan communities. On the whole, gradations of environmental quality, from more pollution to full cleanup, affect WTP realistically in both direction and order of magnitude, thereby satisfying a scope test (National Oceanic and Atmospheric Administration, 1993).

B. *Market-Based Hedonic Estimate*

Welfare estimation for the hedonic model is based on the following assumptions. First, we assume, like many previous studies, that the distance variable (*harbmile*) captures the benefits of site remediation (e.g., Michaels and Smith, 1990; Kohlhase, 1991; Kiel, 1995; Gayer et al., 2000). Second, the hazardous impact of Waukegan Harbor is a localized externality and its effect is felt by the Waukegan community only, and not by the residents of the other cities in Lake County.[30] The significant parameter estimate for the interaction term ln(*harbmile*)**waudum* together with the insignificant parameter estimate for ln(*harbmile*) provide empirical support for a localized effect. Third, noting that the farthest home in Waukegan is more than five miles from the harbor, we consider for the purpose of illustration several distances from the harbor to test for the disappearance of the negative effect of harbor proximity. For partial disappearance of the proximity effect, we use distances of four and five miles from the harbor. For complete disappearance, we consider distances of six, seven, and eight miles from the harbor. A measure of *nonmarginal* benefits associated with the change in the effect of distance would involve a change from the average distance to the harbor for Waukegan homes (2.45 miles) to the above-mentioned distances.[31]

C. *Welfare Comparison Across Models*

Our mean marginal WTP for Waukegan households for an additional mile of *harbmile* is $6,813 in year 2000 prices with a 95% confidence interval ($6,447, $7,179). This implies that Waukegan home values appreciate by $6,813, on average, with a one-mile increase in the distance of the home from the harbor. According to the 2000 census, Waukegan had a total of 15,697 single-family homes. The hedonic estimates of the present value of aggregate welfare for a nonmarginal change in *harbmile* from 2.45 miles (Waukegan mean distance) to 4, 5, 6, 7, and 8 miles are $166 million, $273 million, $380 million, $487 million, and $594 million, respectively.[32] The first two figures approximate partial elimination of the proximity effect, while the last three figures approximate complete elimination of the proximity effect. The aggregate welfare estimates from the RUM approach reported in Table 7 are $249 million for partial cleanup and $535 million for full cleanup. Interestingly, the estimated value gain in partial cleanup in the RUM approach is comparable to the value gain in partial elimination of the proximity effects (raising the distance from 2.45 miles to 5 miles) using the hedonic approach. Also, the estimated value gain in full cleanup in the RUM approach is comparable to the value gain from complete elimination of the proximity effects (raising the distance from 2.45 miles to 8 miles) using the hedonic approach.

D. *Welfare Comparison Across Studies*

To test the external validity of our results, we compare them to three hedonic studies that investigate housing value depreciation due to proximity to hazardous sites. Kohlhase (1991) uses housing sales data from before and after the EPA's announcement regarding the hazardous sites to carry out an ex post analysis of housing value depreciation near Superfund sites in Houston, Texas for the years 1976,

30. This will permit us to use the first-stage hedonic price function to estimate approximate welfare associated with a large change in the distance effect (e.g., Michaels and Smith, 1990; Palmquist, 1992). Also, this assumption ensures that the hedonic equilibrium price schedule will not shift ex post in response to site remediation (Bartik, 1988).

31. See Michaels and Smith (1990) for a similar treatment.

32. For example, a change in the distance effect from 2.45 miles to 4 miles is calculated as $6,813*(4.00 − 2.45)*15,697/1,000,000 = $166 million.

1980, and 1985. Kiel (1995) analyzes housing sales data from Woburn, Massachusetts. She estimates hedonic housing price regression separately for the periods 1975–1976, 1977–1981, 1982–1984, 1985–1988, 1989–1991, and 1992 to specifically investigate the EPA's role in the market adjustment process that started from EPA's announcement phase and continued until cleanup strategies were announced. Both Kohlhase (1991) and Kiel (1995) find a marginal impact of approximately $3,300 in pre-1985 prices, signifying that, all else being equal, average housing value increases by $3,300 if the distance of the property from the hazardous site increases by one mile. Kiel (1995) also finds marginal WTP in nominal terms for the periods 1985–1988, 1989–1991, and 1992 as $3,819, $4,077, and $6,468, respectively. Thus, after accounting for inflation, the marginal WTP of $6,813 in year 2000 prices obtained in our hedonic study compares well with previous studies.

Ihlanfeldt and Taylor (2004) analyze the proximity effect of hazardous sites on commercial property values in Atlanta, Georgia. They report estimates of property value losses for different categories of properties. The average losses in present value according to their estimates are $133,000 per apartment, $495,000 per office building, $29,000 per retail store, $29,000 per industrial establishment, and $85,000 per each vacant property (Ihlanfeldt and Taylor, 2004, Table 4, p. 130). Focusing on the apartment buildings (mean sale price $610,000), the average depreciation is 22%. Our estimate of possible home value appreciation due to "full cleanup" in the survey-based RUM approach reported in Table 7 is $34,130, on average, for Waukegan homes (mean sale price $206,000). This would imply an appreciation of 16.6%.

In the hedonic approach, value appreciation for Waukegan homes for a nonmarginal change in the distance effect under the five distance scenarios—namely from 2.45 miles to 4, 5, 6, 7, and 8 miles—are $10,560, $17,373, $24,186, $30,999, and $37,812, respectively, on average. This would imply an appreciation of 5.1%, 8.4%, 11.7%, 15.0%, and 18.4%, respectively. Although, the definition of a nonmarginal change is different in the two studies, our hedonic estimate of 18.4% appreciation for a complete elimination of proximity (raising the distance from 2.45 miles to 8 miles) and the RUM estimate of 16.6% for "full cleanup" are quite comparable to Ihlanfeldt and Taylor's estimate of 22% value depreciation. One reason for slightly lower percentages in value appreciation in our study compared to the value depreciation in the Ihlanfeldt and Taylor study could be attributed to the long time gap between the study period and initial community knowledge about the hazardous site. Generally, demand and supply for housing are inelastic in the short run, but they tend to become more elastic in the long run, which may moderate the price appreciation associated with cleanup. We note, however, that the Ihlanfeldt and Taylor study samples include only commercial properties, whereas the present sample consists of only owner-occupied residential properties.

E. Implications for the Waukegan Community

Cleanup is economically justified if the benefits outweigh the costs. According to Tsouderos (2004), the anticipated cost of full cleanup of the Waukegan Harbor is $21 million, out of which the city's share is about $6 million. One approach to raising funds for the local share is tax increment financing (e.g., Ihlanfeldt and Taylor, 2004). Under this scheme, the local government issues municipal bonds in an amount sufficient to fund the cleanup efforts. The tax revenue to pay for the annual debt service and to repay the bonds on maturity would come from the increased tax revenue from home value appreciation after site remediation is carried out. The present value of the projected increase in tax revenue for Waukegan is calculated from the survey-based RUM estimate as $14.46 million. In the hedonic approach, for complete elimination of the proximity effects under the three distance scenarios—namely from 2.45 miles to 6, 7, and 8 miles—the projected increases in tax revenue would be $10.25 million, $13.13 million, and $16.02 million, respectively.[33] Thus the issuance of municipal bonds worth up to $6 million to meet the city's share of the cost of remediation appears quite

33. These figures are based on an equalized assessment value of 33.33% of the fair market value prevailing in Lake County and an aggregate property tax rate of 8.098% (see Lake County Property Tax Review Report, 2003). For example, in the case of the survey-based RUM estimate, the present value of an aggregate property tax increase is equal to $536 \times 0.08098/3 = \$14.46$ million.

feasible in terms of annual debt servicing and repayment of the bond on maturity.

F. Limitation of the Welfare Results

One major concern in the present study relates to the large WTP values for non-Waukegan residents in the RUM. These residents, in general, live from 5 miles to more than 20 miles from the harbor. Kohlhase (1991) shows that the effects of an extreme locational disamenity disappear at distances greater than about six miles. Many other studies (e.g., Ihlanfeldt and Taylor, 2004) suggest that the effects dissipate with radial distances shorter than those found by Kohlhase (1991). Our hedonic price function with a significant *harbmile* coefficient for Waukegan homes and an insignificant *harbmile* coefficient for non-Waukegan homes corroborates this finding. The magnitude of the WTP values for non-Waukegan residents can be assessed if we look at the overall value of the local housing stock. In the year 2000, the overall owner-occupied housing stock in Lake County was valued at between \$40 billion and \$60 billion. Thus, using the RUM analysis, our aggregate WTP for Waukegan for full cleanup amounts to approximately 1% of the housing stock, whereas for non-Waukegan it amounts to approximately 20% to 30% of the housing stock value of the county. It is quite possible that many non-Waukegan respondents valued not only "cleanup," but also additional recreational and commercial opportunities that may follow the cleanup.[34,35] Nonetheless, it is hard to justify a value gain amounting to 20% to 30% of the current housing stock.

Large WTP values for harbor cleanup for non-Waukegan residents in the RUM analysis also point to an important contradiction between the two valuation models. The WTP values from the RUM analysis suggest that the impact of the proposed environmental change is widespread, whereas the hedonic model suggests that the impact is localized to the City of Waukegan. The impact of a widespread environmental change on a housing market has been discussed by Bartik (1988) and Palmquist (1988). Both Bartik and Palmquist show that a widespread change may cause an exogenous shift in the hedonic price function ex post. Such a shift in the present context might result in a severe discrepancy between the ex ante and the ex post welfare benefits for the City of Waukegan. However, if the impact is localized, the hedonic price function will not shift ex post and the ex ante hedonic benefits for the residents of the City of Waukegan that we estimate in the present study can be regarded as a close approximation of the ex post benefits. In short, if the survey-based results in the present research are true, then the hedonic ex ante benefits for Waukegan may not reflect the true benefits. On the other hand, if the impact is localized, as suggested by our hedonic model, then the benefits to Waukegan residents may be reliable, but the survey-based estimates for the non-Waukegan communities are questionable.

Another limitation of the welfare results relates to the way the survey design is formulated. For example, our study deviates from a vast majority of conjoint choice studies in that we provide respondents with only two choice options per choice set, whereas many studies have used more than two choice options. While it is not possible to know the appropriate number of alternatives for the present setting with generic choice options, presenting the correct number of options would certainly ensure statistically efficient asymptotic estimates. However, providing two options in an effort to reduce cognitive overload may have produced a survey design that has inadequately addressed the important issues of coping and relevancy, and consequently has resulted in bias in the estimates.[36] The unusually large value of WTP for

34. The survey questionnaire mailed to each household provided a clear and precise definition of cleanup. A summary of these definitions is presented in Table 2. We deliberately avoided mentioning the possibility of redevelopment of the harbor area in the survey for two reasons. First, the City of Waukegan had no concrete plan for redevelopment of the harbor area at the time of the survey. Second, inclusion of the possibility of redevelopment in the questionnaire would have prevented us from carrying out model comparison, since the survey-based RUM approach can capture future benefits of redevelopment, but the market-based hedonic approach cannot.

35. Apart from commercial shipping, Waukegan Harbor is the only harbor in the region that provides multiple water-based recreational opportunities to all the cities included in the sample. Currently, due to contamination, such opportunities are severely restricted. It is possible that there is a significant recreational demand from residents from all the nearby cities. According to Tsouderos (2004), a full cleanup would entail new investments near the lakefront involving recreational boating and the possibility of gambling casinos to give a push to the local economy.

36. Also, see note 7.

non-Waukegan residents mentioned before could possibly be the result of this inadequacy of the survey design. In short, the results of our survey-based RUM analysis, especially the welfare estimates of the residents outside Waukegan should be treated with caution.

VII. CONCLUSION

This article attempts to estimate the benefits of cleaning up toxic contaminants from Waukegan Harbor, a Superfund site on the Great Lakes. The article compares the discrete-choice random utility model and the hedonic property value model in estimating the benefits of cleaning up, using survey-based conjoint choice data on housing preferences and market-based data on housing transactions, respectively, for the same homes. The study generates a number of interesting findings.

First, WTP estimates for small changes in attribute levels are quite comparable between the two models, and the survey-based estimates are consistently lower. Second, gradations of environmental quality, from more pollution to full cleanup, affect WTP realistically in both direction and order of magnitude in the survey-based RUM.

Third, the estimates of property value appreciation obtained for partial and full cleanup are \$249 million and \$535 million, respectively, from the survey-based RUM. A series of estimates to eliminate, partially and fully, the proximity effect associated with the hazardous site obtained from the market-based hedonic model range from \$166 million to \$273 million in the case of a partial elimination and from \$380 million to \$594 million for a complete elimination. These estimates are in year 2000 dollars. Thus the two models are quite comparable with respect to the benefits estimates.

Fourth, benefits estimates in the present study are also compared to a recent study by Ihlanfeldt and Taylor (2004). The loss of property value of apartment buildings near contaminated sites amounted to about 22%. Our estimates of the gains in property values for the proposed remediation account for about 16% in the survey-based approach and as much as 18.4% in the hedonic approach. Thus the two studies generate quite comparable results.

Finally, the present value of the tax revenue from the property value appreciation is estimated as \$14.46 million for "full cleanup" from the survey-based approach. A series of estimates associated with a complete elimination of the negative proximity effects in the hedonic model range from \$10.25 million to \$16.02 million. Thus the study finds that the tax revenues resulting from cleanup should more than cover the City of Waukegan's share of the remediation costs.

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