On the Nature of Compensable Value in a Natural Resource Damage Assessment

Richard T. Carson
University of California, San Diego

Nicholas E. Flores*
University of California, San Diego

W. Michael Hanemann
University of California, Berkeley

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INTRODUCTION

How should the public be compensated for an oil spill which kills thousands of common sea birds or a chemical spill which wipes out an endangered species? How much should the government be entitled to collect from a polluter whose actions have caused long term harm to an ecosystem managed by government? Courts and policy makers are facing these issues with increasing frequency, the *Exxon Valdez* case being only the most prominent in the public eye.

A decade ago, the legal framework for valuing damages to natural resources placed little or no value on most types of physical injuries and particularly those to ecosystems. First, nobody had standing to sue for many types of injury to ecosystems and the natural environment, since they were not legally owned. Secondly, since it was not bought and sold in the market place, the ecosystem effectively had no value under common law.. The dominant approach used by government agencies to compute the value of any damages to an ecosystem was to look up the cost of obtaining replacement specimens in zoological supply houses' catalogues. This practice, of course, had no real basis in economic theory. The zoological supply houses could not have actually supplied the creatures at the catalogue price in the quantities required to offset the injury, the creatures generally would likely not have survived the transportation, and in any case these were not really replacement creatures that were offsetting a reduction in the population but rather existing captive creatures that were being relocated. Congress, dissatisfied with the outcomes from natural resource damage cases, mandated that the executive branch issue regulations under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) for assessing such damages which avoided the obvious problems with common law. The Department of Interior in issuing those regulations took the economic benefit-cost perspective which had long been used for government planning involving natural resource decisions.

Carson and Navarro (1988) laid out a general expression for valuing damages:

$$D = \underset{i=1}{\overset{k}{A}} \left[V_i^R(q_j;\ C) \right] , \qquad (1)$$

where A is the aggregation rule to be used, $i = 1$ to k is the number of agents aggregated over. $V(\bullet)$ is the individual valuation rule used. R is the property right assumed, q_j is the level of physical injuries valued, and C are the components of value (e.g., use value, U, and non-use/existence value, E) which are to be included. The index of agents can be defined so as to enumerate users, potential users, and those who hold only non-use values. Alternatively this index can be defined over geographic areas, identifiable demographic groups, or fractions of the population with different sets of preferences.

The Carson and Navarro formulation in (1) still allows depiction of most of the substantive disagreements among commentators on how natural resource damages should be described. Recent actions both by the courts and in theoretical and applied work have helped reduce the range of possible damage assessment rules. The major decision was made by the District of Columbia Appeals Court in *Ohio v. Department of Interior* (1989) which ruled that Congress intended that total value, that is use plus non-use values, should be measured.[1]

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[1] For a discussion of the implications of the *Ohio* decision see Kopp, Portney, and Smith (1990). The controversy over whether non-use values has not died down in the academic literature. See, for instance, the exchange between Rosenthal and Nelson (forthcoming) and Kopp (forthcoming).

Another major controversy, whether a willingness to pay (WTP) or willingness to accept (WTA) compensation property right should be used is in the process of being resolved. The Department of Interior on the basis of finding that WTA compensation values from contingent valuation studies were unreliable, and that theoretically, WTP values and WTA values should be close. The first finding that WTA values from contingent valuation surveys are unreliable is generally true, although there are some clever studies which appear to have overcome the problems involved in asking a WTA question. The second finding, however, has been shown to be false by Hanemann (1991). From the perspective of welfare economics, WTA compensation is clearly the correct property right. While Hanemann's work holds out the possibility that WTA values can be reliably calculated from WTP values, acceptance of WTA as the appropriate property right has strong implications for how the embedding issue should be treated.

The embedding issue, raised most strongly in a forthcoming paper by Kahnemann and Knetsch has been picked by a number of contingent valuation critics as the most substantial issue facing the use of contingent valuation.[2] Much of this paper deals with that issue; first, from a theoretical perspective, and second, from an empirical perspective by looking at five studies we carried out in the past which contained tests for this type of behavior.

After doing this, we take up a number of other issues related to the nature of compensable values in natural resource damage assessments. Many of these issues are related to the information people have about the resource in question, and revolve around the *ex ante* perspective, typically favored in benefit-cost analysis versus the *ex post* nature of most natural

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[2] For commentaries which accompany the Kahnemann and Knetsch paper, see Harrison (forthcoming) and Smith (forthcoming).

resource damage assessments. Included in this set of issues is the question of when a natural resource damage assessment should be done if values, as might be expected *a priori*, are changing over time. The other set of issues we take up have to do with the nature of the aggregation rule used. This involves two primary questions: what statistic to use to summarize the data and, how to define the market for determining compensable value for an injury to a natural resource. Here we argue, that as one approaches the desired quantity from a theoretical perspective, the estimate of compensable value becomes increasingly unreliable. Further we argue that most of the practical means of dealing with these issues can result in substantial underestimates of compensable value.

THE ISSUE OF EMBEDDING

Central to the embedding issue is the observed phenomenon that when a particular change in a nonmarket good is valued in different contexts, the value estimates may vary accordingly. CV opponents have argued that for this reason, estimates obtained through contingent valuation are without meaning and should not be considered valid. Although several papers have correctly identified the theoretical issue (Hoehn and Randall, 1989; Hoehn, 1991), none to date have shown under what conditions one would expect to observe such behavior. What follows is the development of a simple economic model that captures the flavor of the valuation process and provides highly plausible conditions under which value estimates should vary according to economic theory.

Suppose the consumer of interest freely chooses from n private market goods and 3 goods are provided publicly, but in limited quantities[3]. The consumer takes the prices of each market

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[3] The general case of *m* public goods is provided in Carson and Flores (1991).

good, p_i $i=1,2,\ldots,n$, as given, and for the sake of simplicity, suppose public goods are provided free of charge.[4]

The consumer's preferences for the $n + 3$ goods are represented by a twice continuously differentiable utility function $U(X,Q)$ where X is an $n \times 1$ column vector whose components are the levels of private market goods, x_i $i=1,2,\ldots,n$ and Q is a 3×1 column vector whose components are the levels of public goods provision q_j $j=1,2,3$. $U(X,Q)$ is strictly quasi-concave and strictly increasing in X and Q. Assuming the consumer exhibits optimal behavior, the consumer faces the problem of maximizing $U(\cdot)$ with respect to X, but constrained by the budget condition $p \cdot X = \Sigma p_i x_i \leq y$ where y is the consumer's income and a given level of Q. Since $U(\cdot)$ is strictly increasing the budget constraint will be fulfilled with equality.

Under appropriate regularity conditions, at the optimal choice of X there exists a duality relationship between the above problem and the problem of minimizing the expenditures on private goods, $p \cdot X$, but constrained by the condition $U(X,Q) \geq U^*$ where U^* is a fixed level of utility[5]. Let X^m and X^h represent the solutions to the maximization problem and minimization problem respectively. The duality relationship can be summarized through the equations $U^* = U(X^m,Q)$ and $p \cdot X^h = y$, where U^* is the optimal program in the maximization problem subject to income y and $p \cdot X^h$ is the optimal program in the minimization problem subject to utility level U^*. Both problems have prices p and public goods provision Q in common.

When changes in public goods provision are considered, the minimization analysis is accepted as the appropriate analytical tool. This follows from neoclassical economists' concern

[4] The case where the consumer must pay for the public goods is handled analogously and adds little intuition. Mäler (1974) provides a treatment of this case.

[5] For a summary of these conditions see Diewert (1982).

with the concept of Pareto efficiency and the appealing property that the resulting changes in expenditures necessary to maintain the initial level of utility can be used as a metric for determining the impact of policy changes across individuals.

The optimal program $p \cdot X^h$ is referred to as the restricted expenditure function which we will denote as $e^*(p,Q;U)$. A change in one or more of the levels of public goods provision from Q to Q' should have an effect on $e^*(\cdot)$, due to the fact $U(\cdot)$ is strictly increasing in both arguments. The measure of interest is the difference $e^*(p,Q;U) - e^*(p,Q';U)$. If the change in provision is an increase, then the difference is positive and is referred to as WTP for the change. If the change in provision is a decrease, then the difference is negative and the absolute value of this change is referred to as WTA compensation for the change in the level of provision.[6]

We can exploit the properties of the utility function and define an implicit price vector p^* that satisfies the condition that in a world where the consumer could freely choose the levels of both X and Q, the levels of (X,Q) chosen facing prices (p,p^*) while minimizing expenditures coincides exactly with (X^h,Q) from the restricted minimization problem. Necessary and sufficient conditions for the existence of such unique prices are those already stated on $U(\cdot)$ and all components of X^h positive. The proof of existence follows from a separating hyperplane argument and will not be presented here. Furthermore, it can be shown that $e^*(\cdot)$ is convex in all components of q and the derivative of $e^*(\cdot)$ with respect to q_j is the negative of p^*_j.[7] We should note that each p^*_j is a function of U, p and Q which we will denote as $p^*_j(p,Q;U)$.

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[6] We assume that all public goods effect the level of utility positively.

[7] We refer the reader to Mäler (1974) for a proof of the existence of implicit prices, convexity properties and derivative properties of $e^*(\cdot)$.

In practice quantity changes are discreet, but because of the convexity property of $e^*(\cdot)$, the derivative and cross derivatives of $e^*(\cdot)$, with respect to q_j can be used to qualitatively describe any policy impacts as well as varying valuation contexts.

Critics of the CVM have strongly argued that the variability of WTP estimates due to varying valuation context renders CV useless. However, under plausible conditions we can easily demonstrate that true WTP should vary according to economic theory.

Suppose we are interested in determining the true WTP for an increase in q_1 from level q_1^o to q_1^1. WTP is given by

$$WTP = -\int_{q^o}^{q^1} \frac{\partial e^*(p,Q;U)}{\partial q_1} dq_1 = \int_{q^o}^{q^1} p_1^*(p,Q;U) dq_1$$

The effects of varying valuation contexts can be summarized through the sensitivities of the implicit price of q_1 to changes in q_i for $i=1,2,3$: In a recent *Econometrica* paper, Madden (1991]) has shown how these sensitivities are related to the unrestricted minimization problem.

Suppose the consumer faces no restrictions on Q or X and solves the unrestricted minimization problem with utility level U and prices (p,p^*) given. Then the solution is a set of Hicksian demands (X^h,Q^h) and associated with these $n+3$ functions is the standard substitution matrix, S with entry i,j given by the partial derivative of the *ith* Hicksian demand with respect to the *jth* price, $i,j=1,2, \ldots, n+3$. S can be written as:

$$S = \begin{bmatrix} \frac{\partial X^h}{\partial p} & \frac{\partial X^h}{\partial p^*} \\ \frac{\partial Q^h}{\partial p} & \frac{\partial Q^h}{\partial p^*} \end{bmatrix}$$

This matrix is symmetric and negative semi-definite. Now consider the submartix, **H**, of the substitution matrix which is the *3* x *3* matrix with entry *i,j* given by the derivative of the Hicksian demand for q_i with respect to the price of q_j. **H** can be written as:

$$H = \left[\frac{\partial Q^h}{\partial p^*}\right] = \begin{bmatrix} \frac{\partial q_1}{\partial p_1^*} & \frac{\partial q_1}{\partial p_2^*} & \frac{\partial q_1}{\partial p_3^*} \\ \frac{\partial q_2}{\partial p_1^*} & \frac{\partial q_2}{\partial p_2^*} & \frac{\partial q_2}{\partial p_3^*} \\ \frac{\partial q_3}{\partial p_1^*} & \frac{\partial q_3}{\partial p_2^*} & \frac{\partial q_3}{\partial p_3^*} \end{bmatrix}$$

In the restricted case we are interested in the derivatives of the implicit prices for q_i with respect to the provision level q_j. The relationship between the Hicksian demand substitution submatrix, **H**, and what we will call the implicit price substitution matrix, **R**, is given by **R** = $\mathbf{H}^{-1}$. That is **R** is the inverse of the submatrix **H**. It should be noted that we are assuming **H** is nonsingular in an appropriate neighborhood of the point of interest in our commodity space. The sensitivity of the implicit price of q_1 to changes in the levels of q_i $i=1,2,3$ are given by the first row of S. The definiteness property of the substitution matrix implies the same definiteness of **H** and together with nonsingularity implies **H** is negative definite.

$$R = H^{-1} = \begin{bmatrix} \frac{\partial p_1^*}{\partial q_1} & \frac{\partial p_1^*}{\partial q_2} & \frac{\partial p_1^*}{\partial q_3} \\ \frac{\partial p_2^*}{\partial q_1} & \frac{\partial p_2^*}{\partial q_2} & \frac{\partial p_2^*}{\partial q_3} \\ \frac{\partial p_3^*}{\partial q_1} & \frac{\partial p_3^*}{\partial q_2} & \frac{\partial p_3^*}{\partial q_3} \end{bmatrix}$$

We can write the first row of **R** in terms of the inverse of the determinant of **H**, Δ, and the entries of **H**, h_{ij}, as follows:

$$r_{11} = \Delta(h_{22}h_{33} - h_{23}h_{32})$$

$$r_{12} = \Delta(h_{13}h_{32} - h_{12}h_{33})$$

$$r_{13} = \Delta(h_{12}h_{23} - h_{22}h_{13})$$

From the properties of definiteness, we know Δ is negative and r_{11} is negative which should be no surprise since $e^*(\cdot)$ is convex. However, the signs of the entries r_{12} and r_{13} will be determined by the signs and magnitudes of the off diagonal entries of **H**.

One popular classification of substitutes is the Hicksian measure which considers goods i and j substitutes if the corresponding i,j entry of the substitution matrix is positive. Similarly goods i and j are Hicksian complements if the i,j entry of the substitution matrix is strictly negative.

It follows from the above equations that in the case where all publicly provided goods are strict Hicksian substitutes for one another, r_{12} and r_{13} are both negative[8]. If all public goods

[8] The general case of m substitute public goods can be proved after a bit of work and the same result holds. The general case is proved in Carson and Flores (1991). Furthermore, since we can rearrange the order of variables, this result holds for goods q_2 and q_3 as well.

are complements or a mixture of complements and substitutes, then knowledge of the magnitudes of the elements of **H** are necessary in order to sign the terms of the off diagonal elements of **R**. In studies of environmental amenities, the case of goods being classified as Hicksian substitutes is the most plausible, and if this is indeed the case, then we can make several generalizations about true WTP and WTA in our model.

Assuming all three publicly provided goods are Hicksian substitutes for one another in a sufficiently large neighborhood, we retain all earlier assumptions on preferences and the submatrix **H**.

Proposition 1: WTP for an increase in q_1 is a decreasing function in the levels of $q_j\, j=2,3$.

Proof: Recall from above that WTP can be written as

$$WTP = \int_{q^o}^{q^1} p_1^*(p,Q;U)\,dq_1$$

The derivative of p^*_1 with respect to q_j equals r_{1j} for $j=2,3$. It was shown above that under the substitutability assumption this term is negative. Assuming all q_1, along the path of integration are contained in the above mentioned neighborhood, then for all values along the path of integration, p^*_1 is smaller under higher values of $q_j\, j=2,3$, and therefore, the integral is smaller.

Proposition 2: Suppose we are interested in the WTP for increases in all three goods, and we look at a valuation sequence where goods are valued successively. If we permute the order of sequencing, then the WTP for the change in q_1 will be greatest when valued first in the sequence and smallest when valued last in the sequence.

Proof: This is a direct consequence of Proposition 1. When valued first in the sequence the levels of q_j $j=2,3$ are at the initial level. Any permutation where the change q_1 is valued later will result in a lower implicit price across the path of integration, due to higher levels of the substitute goods. Valuing the change in q_1 last in the sequence will result in the highest levels of substitute goods, and hence the lowest implicit prices.

Proposition 3: WTA compensation for a reduction in q_1 is also a decreasing function in q_j $j=1,2$.

Proof: WTA can be written as

$$WTA = -\int_{q^{o}}^{q^{1}} \frac{\partial e^{*}(p,Q;U)}{\partial q_1} dq_1 = \int_{q^{o}}^{q^{1}} p_1^{*}(p,Q;U) dq_1$$

which is the same integral as WTP with the exception that now the initial level, q^1, is the higher level. All arguments from the proof of Proposition 1 follow.

Proposition 4: Suppose we are interested in the WTA compensation for a reduction in all three publicly provided goods and permute the valuation order. Then the WTA compensation for the reduction in q_1 will be smallest when placed first in the sequence, and largest when placed last in the sequence.

Proof: This is similar to Proposition 2 with the exception that as the change in q_1 is placed later in the sequence, the level of substitute goods is decreasing, and therefore, the implicit price is increasing.

Our results suggest, that with respect to valuing sequences of goods, that WTP and WTA sequences should behave differently. That is, a good should be valued less highly the further out in a WTP sequence it appears, and more highly the farther out in a WTA sequence it appears. Combining our results with those of Hanemann (1991), one concludes that valuing a good first in a WTP sequence will result in a lower compensable value than valuing that good in any order in a WTA sequence. The implication of this is obvious -- valuing a good first using a WTP question in a contingent valuation survey will under estimate the desired measure of compensable value. It can be further shown that valuing the good first in a WTP sequence results in a measure closest to any of the WTA measures.

FIVE EMPIRICAL TESTS OF THE EMBEDDING PROPOSITION

In this section we look at five empirical tests of embedding which have been carried out in studies by Richard Carson in conjuction with others (e.g., Robert Mitchell). These studies cover a fairly broad range of environmental goods. The first compares values for fishable quality national water (Carson and Mitchell, 1991a) to values for the same water quality level for the Mongahela River obtained by Smith and Desvousges (1986). This comparison is similar to that of Kahnemann (1986) in his original Canadian lakes example. The second comparison looks at two different scenarios (Imber, Stevenson, and Wilkes, 1991) involving mining in Kakadu National Park. The third looks at four different scenarios involving preventing water shortages for California households (Carson and Mitchell, 1991b). The fourth involves different risk reductions from trihalomethanes (THMs) in a small town in Illinois (Mitchell and Carson, 1987). The fifth involves different combinations of visibility and health day improvements in Cincinnati (Carson, Mitchell, and Ruud, 1990). Test from each of these studies conclusively rejects the embedding problem, and hence, tend to support the conclusion of Smith (forthcoming) that embedding may be largely a design problem in contingent valuation studies where the good the respondent is asked to value is poorly defined.

One problem with "embedding" is that it is poorly specified in terms of making a hypothesis test. Let us define the following matrix for embedding experiments along the lines of that used by Kahnemann and Knetsch (forthcoming):

I	II	III
a_I		
b_I	b_{II}	
c_I	c_{II}	c_{III}

where I, II, III are independent samples of the population of interest and good *a* encompasses good *b* which in turn encompasses good *c*. All three goods are assumed to provide positive utility. It would be possible to collapse the table to only include the sample I versus sample II experiment or to increase it by to breaking *c* into subcomponents.

From our work in the previous section it is possible to show the following:

(1) If b and $\bar{b}$ are substitutes, then $b_I < b_{II}$;

(2) If c and $\bar{c}$ are substitutes, then $c_I < c_{II} < c_{III}$, and

(3) If (1) and (2) hold, then

$$a_I > b_{II} > c_{III},$$

$$b_I \neq b_{II},$$

$$c_I \neq c_{II} \neq c_{III}.$$

Note that it is often falsely assumed that b^I should equal b^{II} and that $c^I = c^{II} = c^{III}$ should be true. Without specification of substitution elasticities, the embedding proposition generates no testable hypothesis other than those in (1), (2), and (3). The power to test these hypotheses may be quite weak unless a, b, and c generate substantially different contributions to utility or one has very large sample sizes.

The first test of embedding we will look at is a comparison between the value of achieving fishable quality water nationally and that of achieving fishable quality water in the Mongahela river around Pittsburgh. Here we compare estimates from two high quality in-person surveys, one a national sample and the other a Pittsburgh sample using instrument, which were in most regards quite similar except for their depiction of the geographic area of change. Two corrections have been made which favor acceptance of the embedding hypothesis: a CPI correction for the two year difference in the time period in which the surveys were done and a correction for the lower demographic characteristics of the Pittsburgh sample. We compare \$68 ($\sigma = 92$; $n = 564$) for national fishable quality water to \$26 ($\sigma = 39$; n = 211) and get a t-statistic of 4.88 indicating very strong rejection of the embedding hypothesis. Comparisons using other water quality levels on which use the lower variances from the estimated valuation functions result in ever larger t-statistics favor rejection of the embedding hypothesis.

Our next comparison looks at a recent study (Imber, Stevenson, and Wilks, 1990) done in Australia by The Resource Assessment Commission concerning mining in Kakadu National

Park, one of Australia's two major national parks. Contingent valuation survey consisted of two thousand in-person interviews of Australian households with random assignment to one of two scenarios. The two scenarios were based on the environmental groups' view of the risk of mining in Kakadu National Park (MAJOR RISK) and one is based on the mining industry's view (MINOR RISK). The MAJOR difference between the two scenarios was that the MINOR RISK scenario has impacts confined to the local area around the mine while the MAJOR RISK scenario suggests a small probability of impacts over a large part of the park.

The survey used a double bounded discrete choice estimator (Hanemann, Loomis, and Kanninen, 1991) and a Weibull distribution is fit here. A dummy variable for being assigned to the MAJOR RISK version has a t-statistic of 3.95 indicating rejection of the embedding hypothesis. The figure below depicts the survival curves for the two different scenarios. The median for the MAJOR RISK subsample was $A132 with a 95% confidence interval of [$A99 - $A178], while the median for the MINOR RISK scenario was $A60 with a 95% confidence interval of [$A46 - $A78]. The estimated maximum likelihood equation is also given below:

KAKADU CONSERVATION ZONE MAJOR VS. MINOR RISK			
	parameter	standard error	t-statistic
location (α) shape (β) MAJOR RISK	5.171 2.951 0.797	0.143 0.109 0.202	36.08 27.11 3.95

Log Likelihood -2037	N 2000

We now turn to a study of WTP for prevent residential water shortages in California (Carson and Mitchell, 1991). There were four shortage scenarios:

•**Scenario A** is based on an expected **30-35% reduction** from the baseline of the household's current water consumption **once every five years.**

•**Scenario B** is based on an expected **10-15% reduction** from the household's current water consumption **once every five years.**

•**Scenario C** is based on **two years** of expected water shortage out of every five years: one requiring **30-35% reduction** and one requiring **10-15% reduction.**

•**Scenario D** is based on **two years** of expected water shortage every five years, **both** requiring **a 10-15% reduction.**

Respondents were randomly assigned in a telephone survey of 2,000 households using random digit dialing to one of two treatments: (1) Scenario A followed by Scenario C, or (2) Scenario B followed by Scenario D. This allows for two tests of the embedding hypothesis, Scenario A versus Scenario B and Scenario C versus Scenario D. Again, a double bounded dichotomous choice estimator is used with a Weibull distribution. In both case, the t-statistic for the dummy variable indicating the more severe shortage scenario is greater than four indicating rejection of embedding hypothesis. The maximum likelihood estimates as well as the medians and their 95% confidence intervals for each scenario are given below:

Water Reliability Version A vs Version B			
	Parameter	Standard Error	t-statistic

location (α)	135:16	7.18	18.82
shape (β)	0.719	0.02	46.35
Version A	0.333	0.07	4.64
Log Likelihood -2564	N 2000		

Median, 95% CI   Version A 113.24   [102.01, 125.70]
Median, 95% CI   Version B 81.17   [73.04, 90.20]

Water Reliability Version C vs Version D			
	Parameter	Standard Error	t-statistic
location (α)	288.08	21.45	13.43
shape (β)	0.572	0.014	40.28
Version C	0.513	0.104	4.92
Log Likelihood -3070.81	N 2000		

Median, 95% CI   Version C   253.47   [219.42, 292.81]
Median, 95% CI   Version D   151.76   [132.09, 174.36]

Our fourth test of the embedding hypothesis involves WTP for reductions in trihalomethanes (THMs) a common drinking water contaminant. In this study, Mitchell and Carson (1987) randomly assigned respondents to two different treatments: Each treatment asked respondents to value three different risk reductions. A great deal of effort was put into explaining low level risk reductions in terms understandable to average households. The Group A risks were all lower than their corresponding Group B risks. The 117 Group A respondents and 110 Group B respondents were each asked to give their maximum WTP for a sequence of three risk reductions which were increasing in size. Thus, there are three A versus B test of the embedding hypothesis. The tests are given in the table below. Again, even though the sample sizes are fairly small, the embedding hypothesis is clearly rejected in all three instances.

a_1 X = 3.78 σ = 15.23	vs t = 4.16	b_1 X = 15.23 σ = 24.83
a_2 X = 11.37 σ = 23.90	vs t = -2.92	b_2 X = 26.25 σ = 48.11
a_3 X = 23.73 σ = 40.67	vs t = -3.90	b_3 X = 44.27 σ = 38.63

The last test of the embedding hypothesis to be considered is from a study by Carson, Mitchell, and Ruud (1990) of air quality improvements in Cincinnati. Here respondents were given nine air quality improvement programs. They were asked to rank order the programs and then to give their maximum WTP for each program. Respondents were randomly assigned to one of two treatments. One treatment asked respondents to value programs involving improvements in both the number of health (H) days and visibility (V) days while the other treatment asked respondents to value only the visibility improvements of the first treatment. The results of the embedding hypothesis tests are given below. It is interesting to note here that those treatments which should have the most power to reject the embedding hypothesis (V=3; H=3 vs. V=3; H=0), (V=6; H=3 vs. V=6; H=0) and (V=7; H=2 vs V=7; H=0) convincingly reject the embedding hypothesis. The case where both treatments valued the same program (V=5; H=0) results in a t-statistics of only 0.46. Comparisons between programs with a large number of visibility days and only one health day generally result in quite small t-statistics. We provide four figures below which show the CDF's for the following programs (V=18; H=1 vs V=18; H=0), (V=6; H=3 vs V=6; H=0), (V=5; H=0 vs (V=5; H=0), and (V=3; H=3 vs V=3; H=0). The (V=29; H=12 vs V=29; H=0) comparison is only suggestive of a rejection of the embedding hypothesis with a t-statistic of 1.67. This comparison deserves some additional comment because many respondents seem to feel that it was impossible to have that large a change in visibility days without at least some change in health days. This indicates that the goods being compared in embedding hypothesis tests must both be credibly provided. It is often the case that respondents doubt that a large expansive program can or will be carried out while a smaller more specific program is viewed as much more likely to be provided. This of course can result in apparent aberrant results in contingent valuation tests of the embedding hypothesis where treat care is not taken in the description of the two goods being valued.

Visibility (V) and Health (H) Improvements		Visibility (V) Improvement Only
(V=29, H=12) x=119; σ=128	vs t=1.67	(V=29; H=0) x=83, σ=120
(V=23, H=2) x=68; σ=96	vs t=0.45	(V=23; H=0) x=60; σ=93
(V=25; H=1) x=62; σ=99	vs t=-0.28	(V=25; H=0) x=67; σ=99
(V=18; H=1) x=45; σ=69	vs t=-0.06	(V=18; H=0) x=46; σ=71
(V=6; H=3) x=36; σ=44	vs t=3.70	(V=6; H=0) x=13; σ=27
(V=13; H=1) x=35; σ=57	vs t=0.51	(V=13; H=0) x=30; σ=48
(V=7; H=2) x=29; σ=38	vs t=2.50	(V=7; H=0) x=15; σ=29
(V=3; H=3) x=29; σ=41	vs t=3.60	(V=3; H=0) x=8; σ=23
(V=9; H=1) x=23; σ=38	vs t=0.90	(V=9; H=0) x=17; σ=33
(V=5; H=0) x=12; σ=28	vs t=0.46	(V=5; H=0) x=10; σ=25
n=70		n=60

INFORMATION AND THE TIMING OF VALUATION

In practice, one factor which distinguishes environmental valuations conducted in the course of a natural resources damage assessment from those conducted in the course of a benefit-cost analysis of some proposed project or policy measure is that the former are almost always conducted *ex post* while the former are usually conducted *ex ante*. Does this matter and, if so, which is the correct perspective to adopt ?

The choice of perspective matters to the extent that *ex ante* and *ex post* surveys yield different values for the same environmental commodity. Whether this is the case is obviously an empirical question. We are not aware of any efforts to investigate the question systematically, but it certainly would not astonish us if there turned out to be significant differences between *ex ante* and *ex post* values. We are less certain, however, of the direction in which the differences would lie. One might speculate that *ex post* valuations are higher: when you survey people after the accident has happened, they are less complaisant and place a greater value on the damage than they would have had you surveyed them before the accident. However, it is not evident to us that this will always be so. The experience of an event could cut both ways: the damages could turn out to be less severe, more easily manageable, or of shorter duration than people would have expected *ex ante*.

Such differences in value as do occur will be some mix of change in perceptions and change in preferences. What is their significance for natural resources damage assessment ? Welfare economics has long been bothered by changes in preferences -- which set of preferences should be employed to assess a change in utility ? Our view is that this cannot be answered without resort to a value judgment and without reference to the particular context in which the welfare evaluation is to be employed. To the extent that a damage assessment involves a different context than a cost-benefit analysis of a policy program, it may call for a different value judgment -- a different social welfare function -- than that appropriate to the cost-benefit analysis. In particular, damage assessment involves an element of restitution that may well be lacking from, and inappropriate to, the conventional cost-benefit context. In formulating the compensation for any tort, the paramount goal is, surely, to render the victim whole. By definition, this must be determined with reference to the *ex post* rather than the *ex ante* preferences: you want to restore the individual to his *ex ante* level of wellbeing, but this is meaningless if it does not take account of what his preferences are *ex post*. Restitution that satisfies *ex ante* but not *ex post* preferences is no restitution at all.

Our conclusion, therefore, is that it is the *ex post* preferences which should provide the basis for damage assessment. More specifically, it is the *ex post* willingness to accept that, in principle, one ought to calculate.

We would not make the same recommendation for a conventional cost-benefit analysis of a policy program. The social welfare function conventionally applied in cost-benefit analysis pays no attention to the *status quo* and does not define people's wellbeing in terms of changes from the *status quo*. It aggregates (monetary measures of) changes in utility across individuals entirely without reference to whether or not they are experiencing a change from the *status quo*, still less whether that change is a gain or a loss. When dealing with long-term trends in the welfare of a society of anonymous individuals, this may not be an inappropriate approach. When dealing with compensation for wrongs inflicted by tortfeasors on identified individuals, it seems wildly inappropriate.

Some of those who offered comments in 1989 in connection with the revision of the damage assessment regulations suggested that non-use values be admitted only for those individuals who were familiar with the injured resource prior to the accident or release. We would take issue with that assertion precisely because of our position on the primacy of *ex post* preferences in the context of assessing natural resources damages. Suppose you were a victim in an automobile accident that impaired your ability to bend your elbow. Further, suppose that you would have given a low value if you had been surveyed before the accident about the importance you placed on preserving your elbow's flexibility; but, after the accident, you find that this matters more to you than you would have thought and therefore, ex post, you place a high value on preserving your elbow's flexibility. Which is the appropriate value to employ when calculating the compensation to which you are entitled ? We cannot help thinking that it is how you feel about the injury *after it has occurred* that should determine the compensation. Moreover, we cannot see why the same logic should not prevail with non-use values as it surely does for use values.

MEASURING AGGREGATE DAMAGES

In any economic analysis, the aggregation of gains and losses across individuals involves an implicit, if not explicit, value judgment or social welfare function. For the reasons mentioned above, we believe the social welfare function that is appropriate for aggregation in a natural resources damage context is not necessarily the same as that appropriate for a conventional cost-benefit analysis. We will explore this here with reference to two aspects of aggregation -- the use of the mean versus the median as a summary statistic in discrete-response contingent valuation studies, and the issue of whether the gains arising from an oil spill or release of other hazardous substance should offset the losses.

Before proceeding, however, we should emphasize that, in any valuation exercise, the aggregate value can be thought of as the product of two key parameters -- the number of households or individuals who place a non-zero value on the commodity in question, and some measure of the value associated with a typical member of that set of households or individuals. Thus, when we showed evidence above that the values associated with larger versus smaller changes in commodities or amenities such as reliable water supply or air quality vary according to the magnitude of the change, this variation can be associated with either or both of those key parameters: when contemplating two different changes, *fewer* households may place a non-zero value on avoiding the smaller change and/or those who do care about the changes may place a *lower* value on avoiding the smaller change. There is empirical evidence in support of both phenomena.

With regard to the choice of a summary statistic to represent the values of a typical individual, both the mean and the median of the WTP probability distribution are widely employed in the literature. Hanemann (1989) has argued in favor of using the median for conventional cost-benefit analyses, because -- as a value judgment -- he strongly prefers a majority-voting social welfare function to the Hicks-Kaldor potential compensation criterion. If compensation is not actually going to be paid, he regards the Hicks-Kaldor criterion as morally worthless.

In the context of a natural resources damage assessment, however, we would take a different position: we believe that, in principle, the mean is the appropriate summary statistic. The reason is that the context is clearly one of compensation -- not potential, but actual. Suppose there is a small minority of individuals who place a high value on an environmental commodity or service, so that for the overall population the mean value is significantly larger than the median. If the resource is wrongfully injured, we can see no reason to omit those individuals from consideration when the compensation is being determined, even though we would be willing to see them outvoted in the context of a policy decision to, say, increase the supply of that commodity or service. The context is different and it calls for a different social welfare function. In particular, as indicated above, we feel that the element of restitution -- the goal of making everyone whole who was injured -- is especially relevant in a damage assessment context, even though we would be inclined to set such notions aside in other contexts involving conventional policy assessment.

Having said this, we should distinguish between considerations of principle, which we have been arguing thus far, and considerations of practice. While we regard the mean rather than the median to be the theoretically correct welfare measure for damage assessment, this is not to say that we think the mean can be measured with equal or superior accuracy, as compared to the median. To the contrary, we are well aware that in empirical applications the median can be measured far more robustly than the mean. In terms of the distribution function of WTP in a population, the mean is highly sensitive to the position of the right tail: changing the probability model, the observations included in the data set, or the method of estimation can have a great impact on the estimate of the mean, while leaving the estimate of the median virtually untouched. In our view there are two practical solutions. One solution is to employ the median as a robust lower bound on the mean. This achieves robustness, but possibly at the cost of substantially underestimating the theoretically correct measure of compensable value. An alternative, and preferable, solution, is to attempt to develop robust estimators of the mean by turning to semiparametric or nonparametric estimation of the WTP distribution. We are currently investigating this approach together with our colleague Paul Ruud.

Returning to questions of principle, for the same reason that we consider the mean the theoretically concept welfare measure, we would be prepared to argue that the conventional practice of netting out gains from losses is not necessarily appropriate in a damage assessment context. Suppose that, as the result of some wrongful action, people's access to some stretch of shoreline is disrupted; for a period of, say, one month they cannot visit the restaurants, shops, and other businesses located in the affected area. Instead, suppose that they patronize restaurants, shops, and businesses in some other location that is more distant or otherwise less desirable than the area disrupted by the release. They may visit the other place less often than they used to visit the area that was closed down, but from the perspective of the "new" area there has been an increase in business. In principle, there are two sets of losers -- the consumers who lose access to their most preferred location and the owners, workers, etc. associated with the businesses that were closed. The former lose consumer's surplus; the latter lose producer's surplus and rents. There is also a set of gainers -- the owners, workers, etc. associated with the businesses in the "new" area.

The conventional practice would be to subtract the gains to the businesses in the "new" area from the losses to the businesses that were closed, in order to obtain an estimate of the net gain to the business sector as a whole. In a damage assessment context, however, we do not consider that this would necessarily be appropriate. This is because we do not believe that the net gain to the business sector is the item relevant to the analysis. As noted earlier, we believe that in a damage assessment context the social welfare function should pay attention to the *status quo* and define wellbeing in terms of deviations from it. If restitution is part of the goals of the valuation exercise, then the loss suffered by those injured matters, and the fact that somebody else enjoys a gain does not mitigate the victims' loss. The loss to the victims must be compensated by the tortfeasor -- that is surely the primary concern. Whether the other parties can enjoy their gain as a windfall, or are required to disgorge it to the tortfeasor after he has compensated the victim, we would regard as of secondary concern.

The same point can be made in another way. Economists have long recognized the distinction between efficiency and equity in welfare evaluations. However, for the last several decades most economists have been trained to focus exclusively on efficiency and to disregard equity as a practical consideration in their work. But, equity is surely the central concern of tort law in general, and compensation for damages in particular: if there is no concern for equity, these are meaningless bodies of law. It is precisely because of the different roles that equity should play relative to efficiency in damage assessment and program evaluation that we are arguing for different approaches to aggregation in the two types of analysis.

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