Option Wealth and Bequest Values: The Value of Protecting Future Generations from the Health Risks of Nuclear Waste Storage

For Presentation at the Annual Meetings of the AAEA in Long Beach CA

July 28-31, 2002

Mary Riddel

Center for Business Economic Research

University of Nevada

Las Vegas, NV 89154

(702) 895-3191

W. Douglass Shaw

Department of Applied Economics and Statistics/MS 204

University of Nevada

Reno, NV 89557-0105

(775) 784-6701

1. Introduction

In January 2002, Energy Secretary Spencer Abraham recommended Yucca Mountain in Nye County, Nevada as the country's central repository for spent nuclear fuel. The residents of Nevada, particularly those of the Las Vegas Valley located approximately 100 miles from the site, have long expressed opposition to the plan, claiming that the facility poses risks to the health and safety of those living near the repository. In spite of the opposition, the Department of Energy (DOE) plans to begin storing nuclear waste at the site in 2007.

Interestingly, opposition to the site was firm in the 1980s, when many residents were unlikely ever to be exposed to the risks associated with the site (Kunreuther and Easterling, 1991). This suggests that at least some part of the opposition to the site may be attributable to concern for future generations and the risks they could experience if the repository were to open. The concept of bequest value of environmental goods is not new. Krutilla (1967) laid the foundation for preservation benefits of environmental goods including option, bequest, and existence values. Greenley, Walsh, and Young (1981) provided the first empirical estimates of these benefits from a case study of preserving recreation values in the South Platte River Basin in Colorado. Since that time, very little has been published that contains empirical estimates of bequest value of environmental goods.

Like Greenley, Walsh, and Young (1981) we are interested in how the present generation values the uncertain utility of future generations. Past modeling efforts support the concept that the appropriate welfare measure under conditions of uncertainty is measured from an ex ante perspective. Early attempts at developing an ex ante welfare measure relied on the expected utility (EU) model formalized by Von Neumann and Morgenstern (1944) and Graham (1981). When modeling the bequest value of a health and safety risk, the model must account for the uncertain nature of the externality once the program is in place. In addition, when a long-lasting threat is at issue, the temporal component must be clearly elucidated. In an effort to account for the episodic nature of the externality caused by nuclear waste storage, we devise a simple model of intertemporal choice under uncertainty. The model allows for the utility of individuals in this generation to be affected by the consumption of future generations. We present an estimable form of the model that relies on a few, plausible, assumptions.

Our model also allows us to examine another issue surrounding health-risk valuation. Although the expected utility theory predicts rational behavior, there is a plethora of experimental evidence that the EU model falls short in predicting actual human behavior. In response, the estimates presented here are based on a slight deviation from the EU model formalized by Cameron (2001) and Riddel and Shaw (2001). Specifically, the model departs from the linear-in-risk EU model with the associated welfare measure, the option price, by including the event variance in addition to the probability of the event occurring. This produces a quadratic relationship between risk and what we term quasi-expected utility. The relationship between our ex ante welfare measure, termed option wealth (OW), and risk matches the peculiar pattern of risk valuation observed in the experimental setting. More precisely, including the event variance reveals that people place a higher marginal value on low-risk events than high-risk events because of aversion to the increase in uncertainty surrounding the high-risk event.

Using responses from a survey that questioned Southern Nevadans about perceived risk, willingness to accept (WTA), and household characteristics, we estimate the parameters of the quasi-expected utility model. We find strong evidence of a bequest motive. In fact, approximately one third of the social cost borne by a household from the repository can be attributed to costs to future generations. The results support the early findings of Greenley, Walsh, and Young (1981) that bequest motives may be a significant component of estimated nonmarket values. However, the nonzero value for the bequest motive estimated here is inconsistent with past research such as Deacon and Shapiro (1975) that found no basis for altruism in public-good provision.

The paper is outlined as follows. Section 2 presents the theoretical model of bequest value within the expected utility difference framework. Section 3 discusses the survey and data used in the modeling effort. Section 4 describes the empirical model and results. Section 5 concludes with some implications for environmental policy when altruistic or bequest motives dominate values.

2. The Model

Assume that individual i's lifetime utility is a function of their exposure to some adverse event represented by $\overline{q}_i$ where $\overline{q}_i$ equals q_i when exposure occurs and zero when it does not occur. The lifetime probability of individual i being exposed to the adverse event is equal to π. Similarly, individual j's exposure to the adverse event is represented by the vector $\overline{q}_j$ and also occurs with probability π. Let A represent the lifetime payment necessary to compensate an individual for bearing the risk of $\overline{q}_i$, and A_F represent the portion of that payment that would be foregone if future generations were protected from the risk. Define $A_{C,t}$ and $A_{F,t}$ as the payments, at time t, corresponding to lost own utility and foregone future payments. If θ_C^t and θ_F^t are the discounting functions for own utility and future utility, respectively, then $A_C = \sum_{t=0}^{T} \theta_C^t A_{C,t}$ and $A_F = \sum_{t=0}^{T} \theta_F^t A_{F,t}$ are the total lifetime payments, after discounting, for a general discounting function. Thus, A_F may be interpreted as the bequest value associated with nuclear waste storage and $A_C = A - A_F$ is the portion of payment meant to compensate for own lost utility. Finally, define PY as permanent income. Then, analogous to Cameron (2001) we posit the indirect random utility function, $V^m = g(PY) + h(q, X) + \varepsilon^m \;\; m = 0,1$ where $g(\cdot)$ is an additively separable monotonic function of income. Then the indirect utility functions with and without the program, respectively, are:[1]

$$
\begin{aligned}
V^0(PY,0) &= g^0(PY) + V_C(0,X) + \varepsilon^0 \\
V^1(PY,q) &= g^1(PY, A_C, A_F) + V_C(q,X) + V_F(q) + \varepsilon^1
\end{aligned}
\tag{1}
$$

where X is a vector of individual-specific attributes affecting utility. If $\frac{\partial u}{\partial q_{it}} < 0$, then the function is convex to the origin. The OW is defined as the minimum lifetime payment that an individual would accept prior to the imposition of the policy to bear the risks of the episodic externality. In other words, OW is the state-independent payment that maintains expected utility at the level prior to the imposition of the policy. As such, it is an ex ante welfare measure that reveals the maximum WTA prior to the resolution of the uncertainty surrounding the episodic externality.

To allow for estimation, we must choose specific functional forms for the utility functions. Assume indirect utility functions with and without storage are $V^0(PY,0)$ and $V^1(Y,q)$, respectively, as follows:

$$V^1 = \alpha_1' X + \beta \ln(PY + A_C + A_F) + f_C(q) + f_F(q) + \varepsilon^1 \tag{2}$$
$$V^0 = \alpha_0' X + \beta \ln PY + \varepsilon^0$$

Here, A_C and A_F are equal to the WTA arising from losses in own utility and other utility, respectively. For simplification we allow $f_C(q)$ and $f_F(q)$ to be linear in q so that $f_C(q) = \lambda_C q$ and $f_F(q) = \lambda_F q$. Thus, the difference in utility with and without the project is:

$$V_1 - V_0 = \beta \ln\left(\frac{PY + A_C + A_F}{PY}\right) + \alpha X + \gamma_C q_C + \gamma_F q_F + \varepsilon$$

where $\varepsilon_t = \varepsilon_t^1 - \varepsilon_t^0$. Taking the expectation over q gives:

$$E_q[V_1 - V_0] = \beta \ln\left(\frac{PY + A_C + A_F}{PY}\right) + \alpha X + \gamma_C E[q_C] + \gamma_F E[q_F] + \varepsilon \tag{3}$$

If $\pi_C = \pi_F = \pi$ then:

$$E_q[V_1 - V_0] = \beta \ln\left(\frac{PY + A_C + A_F}{PY}\right) + \alpha X + \pi(\gamma_C + \gamma_F) + \varepsilon \tag{4}$$

Following Cameron (2001), solving for $A_F + A_C$ when $E[V^1 - V^0] = 0$ gives the OW arising from intergenerational utility, OW_F:

$$OW_F = PY * \exp\left[-\left(\frac{\alpha X + \pi(\gamma_C + \gamma_F) + \varepsilon}{\beta}\right)\right] - PY - OW_C \tag{5}$$

$$E[OW_F] = PY * \exp\left[-\left(\frac{\alpha X + \pi(\gamma_C + \gamma_F)}{\beta}\right)\right] \exp\left[\frac{1}{2\beta^2}\right] - PY - OW_C \tag{6}$$

Equations 1-6 are presented in terms of bequest motive. Of course, individuals may value not only the consumption of future generations, but that of others currently living. If we define PY as income rather than permanent income and let A_C and A_F be payments for the current period only, then the theoretical model may also be useful in describing contemporaneous altruism rather than bequest value. For the purposes of this paper, we confine ourselves to the estimation of bequest value. However, the model, as developed, is not limited in this respect.

The formula in (6) offers straight-forward estimation of the expected OW. Operationally, a survey can elicit the total WTA the policy from an ex ante perspective. A subsequent query may educe the portion of the payment that compensates for reductions in own utility from risks faced by future generations. The following section describes such a survey. We question residents of Southern Nevada about the Yucca Mountain nuclear waste repository to determine their risk perception, option wealth, and the portion of that option wealth attributable to bequest motives.

3. Yucca Mountain Application: The Survey and the Data

Residents of Southern Nevada were surveyed because they are most likely to be affected by health risks from the repository. A random sample of households in Southern Nevada was selected and telephoned by a trained interviewer.[2] They were asked to participate in the survey. If they agreed, they were sent a booklet describing the Yucca Mountain nuclear waste repository and the potential risks and damages that it may pose to those living in Clark County, Nevada. The damages and risks presented in the booklet vary with distance from the site. During the initial phone call, a telephone interview was scheduled for a later, convenient time. With the information booklet in hand, the household member was asked to report the risk they thought was associated with the repository. Risks were presented using a risk ladder (see Carson and Mitchell, 2000; or Loomis and duVair, 1993). Several different risky events are featured on the risk ladder giving the number of deaths per 100,000 in the population associated with these events or activities. Respondents were encouraged to provide either a point estimate or, if more comfortable, a range for the risks. We assume that those who were able to give a point estimate of the risk were certain; whereas, those expressing the range for the risk were doing so to express uncertainty about what risk they would face.

Following the risk assessment, the respondents were told that a program could develop involving their choice to relocate to a safe distance from the site. Respondents were told their moving costs would be paid if they chose to move. Respondents were then offered a federal tax rebate and asked if they would stay at their present location or relocate in response to the increase in risk to their health and safety from the storage facility. If a respondent chooses to relocate they will not face any risk from the repository, though no compensation is received. If the compensation offsets an individual's lost utility from the increase over the baseline risk, the respondent prefers to stay and accepts the compensation in lieu of the costs associated with nuclear waste exposure risk.

The survey collected information regarding income, personal characteristics such as sex and age, and other factors that may influence risk valuation. A series of questions were asked to assess the WTA of the respondent concerning transportation and storage of the nuclear waste. The bid amount was presented as a federal tax rebate for residents near the facility. This proposed method of payment is reasonable, as the nuclear waste program of the federal government required that the host state be compensated (Flynn and Slovic, 1995), and states can then use these federal dollars to compensate or relocate households asked to bear additional risks.[3] Also, local politicians, including the ex-governor of Nevada, have touted the idea of ending resistance to the repository in exchange for compensation.

With the stated subjective risk in mind, respondents were questioned about their WTA the repository using the double-bounded format (Hanemann, Loomis, and Kanninen, 1991). During the first round, the respondents were asked if they would accept a stated amount of money for bearing the risk from the repository or if they would relocate to protect themselves from the risk. The amount of money was varied over respondents according to a pre-arranged bid schedule. If they refused compensation and chose to move, the bid was stepped up for round 2, and the question was asked again at the higher-bid amount. If the answer was yes, a lower bid amount was offered.[4] Following the WTA questions aimed at storage, we next asked respondents the following question:

Still assume that a transportation route has been chosen that cannot cause adverse health impacts to you or your family. Suppose that a new technology, transmutation, exists that will make the radioactive material at Yucca mountain harmless in ___ years. The treatment facility will be located at Yucca Mountain. The technology is very expensive. Realizing that the technology will not cut health risks currently, but would get rid of them altogether in the future, would you be willing to accept ________ per year in compensation for the Yucca Mountain site? YES ______ NO _______
IF YES, GO TO A. IF NO GO TO B.

a. If yes, would you be willing to accept ____ less per year? YES ____NO _____

b. If no, would you be willing to accept ____ less per year? YES ____NO _____.

Again, the double-bounded format was used. The time horizon until transmutation becomes effective and the bid amount were varied over the respondent.

Of those contacted, 24 percent completed the survey. This response rate is relatively high for the highly transient Nevada community, reflecting the interest in the topic. Nevertheless, the response rate is low compared to other valuation studies. Thus, we need to carefully compare the demographic profile to that of the larger Clark County population. Those responding to our survey were slightly more affluent than the population as a whole. Mean household income in Clark County is $41,657 compared to our sample-mean income of $51,100. And, as in many surveys, the sample was modestly skewed toward older individuals: 21 percent of Clark County households contain at least one retiree, and 24 percent of the households sampled contained retirees. Other demographics features of the sample were similar to those reported by the U.S. Census Bureau for Clark County.

4. Empirical Model

We estimate the expected value of OW in three steps. First, individual-specific risk and the associated parameter variance are estimated for each respondent who reported uncertainty about the probability of an accident. Next, these estimates are combined with reported individual-specific risk values reported by “certain” respondent and a quasi-expected utility model as in equation (5) is estimated. Finally, E[OW] is estimated using the parameters from equation (5) and the formula in (6).

4.1. Modeling Uncertainty about Risk

The empirical model is constructed to align with the theoretical model in (6). Therefore, to begin, we must estimate the mean subjective risk for uncertain respondents.[5] Using the risk ladder, respondents were asked to report either a point estimate or a range of the risk they felt they would bear from transporting the nuclear waste along the proposed route. The respondents were permitted to give estimates that exceeded the scale provided on the ladder. Although a few respondents (less than 5 percent) reported that the risk either exceeded or fell short of the ladder's range, the majority of individuals were able to place the risk somewhere along the ladder.

We assume that the perceived risk is a linear function of X_i, a vector containing household income and individual specific traits, so that (suppressing the individual i subscript for ease of exposition)[6]:

(7) $$deaths = \theta ' X + \mu \;.$$

If $\mu \sim N(0,\sigma_{\mu}^{2})$ then $E[deaths] = \theta ' X$. The parameters θ and σ_{μ}^{2} can be estimated by observing that:

(8) $$\begin{aligned}
&P\{a < deaths < b\} = P\{a,b\} = \Phi((b-\theta ' X)/\sigma_{\mu}^{2}) - \Phi((a-\theta ' X)/\sigma_{\mu}^{2})\\
&P\{deaths > a\} = P\{a,\infty\} = 1-\Phi((a-\theta ' X)/\sigma_{\mu}^{2})\\
&P\{deaths < b\} = P\{-\infty,b\} = \Phi((b-\theta ' X)/\sigma_{\mu}^{2})\\
&P\{deaths = pt\} = P\{pt\} = \phi((pt-\theta ' X)/\sigma_{\mu}^{2}).
\end{aligned}$$

Where, $a, b,$ and pt are the lower and upper bounds and point estimate, respectively, offered by the respondent. Individual i's contribution to the log-likelihood function is:

(9) $$\ln L = I_{\{a,b\}} \ln P\{a,b\} + I_{\{b,\infty\}} \ln P\{b,\infty\} + I_{\{b,\infty\}} \ln P\{-\infty,a\} + I_{\{pt\}} \ln P\{pt\} \;.$$

The parameter estimates and standard errors of two competing maximum-likelihood models are reported in Table I. The results reveal systematic variation in the reported subjective-risk measure. Risk perception has a well-defined variation for different genders; females, on average, report a higher subjective risk than do their male counterparts. The finding of more risk aversion for women is supported elsewhere in the literature (see Jianakoplos and Bernasek, 1998). Respondents with health insurance perceive less danger from the nuclear waste storage facility than those without health insurance. These findings are similar to those of other risk-perception studies (citation, Viscusi).

Income influences risk perception quadratically. Lower-income households perceive less risk. However, as income increases towards $81,000, the effect diminishes. At higher incomes, the risk perception is increasing in income. Thus, the poorest and wealthiest households gauge the highest risk from nuclear waste storage, all else equal. The motivation behind the quadratic relationship is not clear. The model may be fitting the quadratic relationship because it is overly leveraged by a few high-income households reporting higher-than-average risk. However, 17 percent of our sample households have an income over $80,000, a relatively accurate representation of the local income distribution. Thus, we accept the quadratic relationship as the preferred functional form.

The estimated risk for uncertain respondents is significantly higher than that for certain respondents. The model in Table I predicts a mean average death rate of 733 deaths in 100,000 for uncertain respondents compared to 689 deaths in 100,000 for certain respondents. The overall subjective death rate is 710 in 100,000. This is thousands of times higher than the death rate of 0.08 in 100,000 reported by the DOE. The difference in risk perception between the DOE and the general public becomes critically important with respect to estimating ex ante welfare measures. Equations 5 and 6 suggest that the level of risk perceived by the respondent plays an important role in their ex ante value. Presumably, increasing risk increases WTA and vice versa. Thus, risk perception remains a key policy variable.

We combine the stated death rate for certain respondent with the death rate predicted by the model in Table I to form a point estimate for each individual of the expected death rate. The next step is to develop a response probability model of willingness to forego compensation in lieu of future risk reduction. The following section presents a model that estimates the amount of option wealth that individual i is willing to contribute to future risk reduction.

4.2. The Response Probability Function and the Option Wealth Function

The probability that individual i defers compensation is related to income, the level of perceived risk, the variance of the risk, and individual-specific characteristics that make some individuals more likely to favor future generations. These traits include a self-reported measure of the respondent’s health status, graded from 1 to 5 with 1 representing poor health and 5 representing excellent health, the indicator variable, FEMALE, and a measure of education, EDUC, that begins at zero for those that didn’t finish high school, 1 for those who did, and increases by one for each year of education past high school.

According to equations 5 and 6, the level of perceived risk may also play an important role in determining risk-based welfare measures. However, past research has repeatedly shown that people tend to overvalue unlikely and unfamiliar events, whereas they tend to undervalue familiar and relatively likely events (Viscusi cites here). For instance, people are willing to pay large amounts to increase the safety of air travel, where accidents are rare though hesitant to invest the same amount in auto safety which has a much higher death rate. To capture this effect, we include the variance of the risk in the model. Since the probability of an accident, π , is best described by a Bernoulli random variable, the variance is equal to $\sigma_B{}^2 = \pi(1-\pi)$. We estimate this variance as $\hat{\sigma}_B{}^2 = \hat{\pi}_i(1-\hat{\pi}_i)$, where $\hat{\pi}_i$ is equal to the subjective risk, either reported by the individual for "certain" respondents or computed using the parameter estimates from Table II for "uncertain" respondents.

The empirical model that follows was developed by Hanemann, Loomis, and Kanninen (1991) for estimating welfare measures from double-bounded contingent valuation data. Assuming a normal WTA distribution, the response probabilities are given by:

$$(10)\quad \begin{aligned} &P\{Yes/Yes\} = P^{yy} = F(R_d), \\ &P\{Yes/No\} = P^{yn} = F(R) - F(R_d), \\ &P\{No/Yes\} = P^{yy} = F(R_u) - F(R), \ and \\ &P\{No/No\} = P^{nn} = 1 - F(R_u) \end{aligned}$$

$F(R_j) = \Phi(\alpha' X + \beta[(\ln(W + K_I)/W)] + \gamma_1\hat{\pi} + \gamma_2\hat{\sigma}_B^2)$, K_I is the initial compensation offered, and K_{Iu} and A_{Id} are the step-up and step-down bids in the follow-up question, respectively. The contribution to the log-likelihood function for respondent i is:

$$(11)\quad \text{Ln } L_i = I_i^{yy}\ln \Phi(R_d) + I_i^{yn}\ln(\Phi(R) - \Phi(R_d)) + I_i^{ny}\ln(\Phi(R_u) - \Phi(R)) + I_i^{nn}\ln(1 - \Phi(R_u)).$$

where I^{jk} with j = yes or no and k = yes or no are indicator functions for the response to the initial and follow-up question, respectively.

4.3. Empirical Results

Table II reports the results of two maximum-likelihood models corresponding to two different sets of explanatory variables used in the likelihood function. The model results support the hypothesis that some fraction of households will move to protect themselves from the risks associated with nuclear waste transport. For all models, the estimate of the coefficient of the income term, $\hat{\beta}$, is positive and significant. The coefficient of the death rate is negative and significant. People that perceive more risk from nuclear waste storage are, at the margin, less likely to agree to contribute some of their stated WTA toward mitigating future damages from the Yucca Mountain site. However, according to equation 6, OW is negatively related to the discounted future risk, but positively related to lifetime risk associated with the repository. Thus, as perception of risk increases, so do intergenerational transfers of OW, whereas WTA current risk is increasing in the subjective-risk measure as expected. The coefficient of variance, $\hat{\pi} - \hat{\pi}^2$, is negative, supporting a quadratic relationship between expected utility and the death rate. The quadratic relationship acts to dampen the responsiveness of the estimated OW to the changes in the subjective death rate for extreme death rates. As risk becomes very high, a household's responsiveness to increasing risk begins to fall off sharply.[7]

The health of the respondent plays a significant role in determining the share of OW that should be used for future risk reduction. Healthier respondents are willing to transfer less wealth to coming generations. The results also reveal that the age of the respondent affects intergenerational transfers. Younger respondents are more likely than older respondents, at the margin, to agree to intergenerational transfers. Controlling for risk perception, women are less likely than men to support the transmutation program, indicating that they are willing to contribute a smaller portion of their OW to protecting future generations.

Using equation 6, evaluated at the mean responses for each independent variable, the estimate of the component of OW attributable to altruistic intergenerational utility is \$10,480. The value of the lifetime storage risk is estimated to be approximately \$27,500. Thus, the intergenerational component is slightly more than one third of the total lifetime value of storage risk. Other studies have found evidence of altruistic behavior. Popp (2001) found evidence of altruism using the results of a 1990 survey of demand for environmental quality. Greenley, Walsh, and Young (1981) found positive bequest value for preserving water quality in the South Platte River Basin, Colorado. However, their modeling approach is very different from ours. In particular, they do not directly assess the effects of health risk to future generations in the valuation scheme. Because of this, their model deviates quite strongly from the option value models proposed by Graham (1981) and Cameron (2001). This is the first study, to our knowledge, that estimates the dollar value of OW derived from future generations' utility within an EU framework.

5. Conclusion

This paper presents theoretical and empirical models of bequest value for high-level nuclear waste storage. The bequest value is framed in terms of the portion of OW that a household is willing to contribute to protecting future generations from health risks associated with nuclear waste storage. We find that respondents are willing to donate approximately one third of their total OW from a particular project to protecting future generations.

The finding of positive time-based altruism has important implications for contingent value estimates. How much of the benefit assumed to accrue to current households actually accrues, in the mind of the survey respondent, to future generations or other households in the present generation? Policies formulated to equilibrate costs and benefits may be very different if those values are delivered at different points in time. Of course bequest value, rather than current period altruism, is considered here. Nevertheless, this opens the door to household utility functions that include the utility of other, contemporaneous, households. Here, too, environmental policy can be misdirected if the value has an important spatial component.

References

Cameron, T.A. 2001. “Updated Subjective Distributions for Future Climate And Individual Option Prices For Climate Change Mitigation,” Discussion paper, Dept. of Economics, University of California, Los Angeles.

Deacon, R. and P. Shapiro. 1975.”Private Preference for Collective Goods Revealed Through Voting on Referenda,” *American Economic Review* 65(5):943-55.

Carson, R.T. and R.C. Mitchell. 2000. Public Preferences Toward Environmental Risks: The Case of Trihalomethanes. Forthcoming in Handbook of Contingent Valuation, A. Alberini, D. Bjornstad and J. Kahn (eds.). Brookfield, Vermont: Edward Elgar Press.

Nicholas E. Flores, 2002. “Non-Paternalistic Altruism and Welfare Economics,” *Journal of Public Economics*, forthcoming.

Flynn, J. and P. Slovic. 1995. “Yucca Mountain: A Crisis for Policy: Prospects for America’s High-Level Nuclear Waste Program.” *Annual Review of Energy and the Environment*. Vol. 20: 83-118.

Graham, Daniel A. 1981. “Cost-Benefit Analysis under Uncertainty,” *American Economic Review*, 71(4): 715-725.

Greenley, D.A., R. Walsh, and R. Young. 1981. “Option Value: Empirical Evidence From a Case Study of Recreation and Water Quality,” *The Quarterly Journal of Economics*, Vol. 96, Issue 4 (November), 657 – 673.

Hanemann, M., J. Loomis, and B. Kanninen. 1991. “Statistical Efficiency of Double--Bounded Dichotomous Choice Contingent Valuation,” *American Journal of Agricultural Economics*, Vol. 73(4), 1255-1263.

Jianakoplos, N.A. and A. Bernasek. 1998. “Are Women More Risk-Averse?” *Economic Inquiry*, Vol. 36 (October):620-30.

Kunreuther, Howard and Douglas Easterling. 1990. “Are Risk-Benefit Tradeoffs Possible in Siting Hazardous Facilities?” *The American Economic Review*. May 1990, 80(2); p. 252-256.

Krutilla, John V. 1967. “Conservation Reconsidered,” *American Economic Review*, Vol. 27, Sept. 1967, 777-86.

Loomis, J. and P.H. duVair. 1993. “Evaluating the Effect of Alternative Risk Communication Devices on Willingness to Pay: Results from a Dichotomous Choice Contingent Valuation Experiment,” *Land Economics*, Vol. 69 (3): 287-98.

Riddel, M. and W.D. Shaw. 2001. “Episodic Emissions and Nuclear Waste Transport: The Case of Yucca Mountain,” Working Paper, Dept. of Economics, University of Nevada, Las Vegas, NV.

Viscusi, K. 1989. “Prospective Reference Theory: Toward an Explanation of the Paradoxes,” *Journal of Risk and Uncertainty*, Vol. 2 (Sept.): 253-64.

Viscusi, W.K., 1978. “Health Effects and Earnings Premiums for Job Hazards,” *Review of Economics and Statistics,* 60(3) Aug. 408-416.

Von Neumann, John and O. Morgenstern. 1944. *Theory of Games and Economic Behavior*, Princeton, NJ: Princeton University Press.

Table I. Model of Subjective Fatality Rate: Dependent Variable Is the Number of Deaths per 100,000 People

Parameter	Estimate	Std. err.	Prob.
C	930.50	221.75	0.00
Insurance	-118.63	177.72	0.25
Income	-7.86	5.27	0.07
Income^2	0.05	0.03	0.08
Female	199.23	106.94	0.03
σ^2	1863.64	287.88	0.00

Table II. Interval Data Probit Model for the Indirect Utility Difference Function: Dependent Variable Equals 1 if the Respondent Reports They Will Defer Some Compensation in Exchange for Future Public Safety

Parameters Estimates	Model I	prob	Model II	prob
C	1.3937	0.0002	1.3060	0.0007
ln(Y+A)/Y))	2.1798	0.0000	2.1934	0.0000
$\hat{\pi}$	-0.7722	0.0000	-0.8144	0.0000
Female	-0.1651	0.1471	-------	-------
Educ	0.0390	0.0780	0.0437	0.0696
Health	-0.1345	0.0712	-0.1312	0.0643
Age	-0.0114	0.0021	-0.0114	0.0048
$\hat{\pi}-\hat{\pi}^2$	-0.0051	0.0214	-0.0053	0.0177
Log-likelihood		-307.7		

Endnote

[1] In other words, the utility function for individual i is:

$$U(X, q_i, q_j) = U_{own}(X, q_i) + U_{other}(q_j)$$

[2] The phone-mail-phone method frequently used in contingent value studies is applied here to obtain responses to a sample of Nevada residents. While a national sample is ideal for a study to assess transportation risks for the entire population, getting this large a data set goes beyond the scope of this study. In the discussion of the results, we remind the reader that Kunreuther and Easterling (1990) found similar results based on their Nevada and national samples. Nevertheless, we note that our inferences are confined to a small group, perhaps any population of individuals with similar demographic characteristics to our sample: those who would be faced with transporting nuclear wastes on a route located near their household.

[3] Under the 1987 amendments to the Nuclear Waste Policy Act, Nevada was to be compensated at $10 million per year during the site-characterization phase, and $20 million per year once wastes began to be delivered to the site.

[4] We assume that the reader is familiar with the double-bounded procedure. Hanemann, Loomis, and Kanninen (1991) is the standard reference.

[5] Viscusi (1989) proposes that we use the individual’s prior and updated assessments of risk in a Bayesian approach to risk assessment. Regardless, only the current estimate is relevant to the expected utility function. Thus, acknowledging that people will update not only the mean, but the variance of their subjective risk and consequently their option price as future information becomes available, we use their current risk perception in the model.

[6] The death rate must fall in the interval (0,1). Therefore, we estimated several models including a censored tobit model, a beta model like that used by Heckman and Willis (1977) and the linear probability model. We choose to model deaths, rather than the death rate, for uncertain respondents assuming death counts are normally distributed. This approach offers robust parameter estimates and provides for more respondent-specific variation in the response probability function than do the alternative models.

[7] The marginal impact of increasing risk on the probability of transferring a portion of OW is perversely positive for very high levels of risk. We do not consider this a fault of the model, however, because the region where the marginal impact is positive is outside the range of the reported risks.