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THE FORMATION OF ECONOMIC VALUES†

Are Risk-Benefit Tradeoffs Possible in Siting Hazardous Facilities?

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Ever since Alfred Marshall introduced the notion of consumer’s surplus into the literature as a measure of well-being, economists have been interested in determining the amount of compensation required to leave individuals indifferent between the status quo and a new situation where less of a commodity can be consumed (for example, due to an increase in prices). The Hicksian and Kaldor-Hicks criteria of specifying compensation variations may be appropriate for normal market goods where there is a well-specified demand curve. The analysis is less applicable for dealing with environmental resources where elements of risk are involved, or there exist public good features that make it difficult to estimate people’s values for different amenities (V. Kerry Smith, 1989).

This paper investigates the question of the appropriate role that providing benefits to a host community (possibly in the form of compensation) can play in improving the chances of siting a facility that is perceived to be potentially hazardous.

In Section I, we develop a simple two-period expected utility model to explain preferences for benefit packages. The empirical analysis examining the predictive power of this model will be related to the following problem of current interest:

The U.S. Congress is attempting to locate a site for storing high-level radioactive waste from commercial nuclear power plants in the United States. An underground repository is to be constructed 2000 feet below the earth’s surface for the purpose of permanently storing nuclear waste shipped in casks from power plants around the country. Once filled to capacity, the repository would be sealed to minimize any radiation leakage.

Based on the results of a telephone survey of residents of Nevada regarding their attitudes toward a high-level nuclear waste repository, we suggest ways that the expected utility model might be modified to take into account behavioral factors that are not normally considered part of individual models of choice under uncertainty. These factors may be useful in determining when compensation will be a useful tool in facilitating the siting process.

I. An Expected Utility Model for Siting Facilities

We employ an expected utility model that separates the period in which the siting decision is made from the period during which residents of a community are exposed to risks. Consider an individual who is to receive some level of benefits (B) in return for accepting a nuclear waste repository in his or her backyard. Once the repository is on line, there is a probability p of an accident with negative consequences L. We assume that the person’s utility for the option of having...
the repository is given by a two-period additive utility function,

\[ U(y, R) = U_1(y_1, R_1) + U_2(y_2, R_2), \]

where \( y = (y_1, y_2) \), \( R = (R_1, R_2) \), \( U_1 \) represents the utility of the individual period \( t \), \( y_t \) represents income in period \( t \), and \( R_t \) represents the consequences of a repository during \( t \). We further assume that each of the \( U_t \) satisfies the von Neumann-Morgenstern axioms.

Under the status quo, \( R_1 = R_2 = 0 \). If the individual accepts a repository with benefits package \( B \) provided in period 1 and risk \((p, L)\) existing in period 2, the expected utility is

\[ U_1(y_1, B) + [(1 - p)U_2(y_2, 0) + pU_2(y_2, L)]. \]

The level of benefits \( B^* \) where an individual is indifferent between maintaining the status quo or accepting the repository is given by

\[ U_1(y_1, 0) + U_2(y_2, 0) = U_1(y_1, B^*) + [(1 - p)U_2(y_2, 0) + pU_2(y_2, L)]. \]

This benefit level \( B^* \) represents a willingness to accept (WTA) amount. It is instructive to rearrange equation (2) as follows:

\[ U_1(y_1, B^*) = U_1(y_1, 0) = p[U_2(y_2, 0) - U_2(y_2, L)]. \]

The model indicates that an individual's WTA amount should be predicted primarily by the perceived likelihood of a repository accident and the resulting consequences. Assuming \( U_1 \) is monotonic in \( R_1 \), it also follows that as the level of \( B \) increases, more individuals should find the repository an attractive option relative to the present situation. These hypotheses are tested below.

II. Empirical Analysis

This survey was designed to determine the role of the proposed high-level nuclear waste repository at Yucca Mountain, Nevada, which provides an unusual opportunity to examine the importance of different factors in determining individuals' attitudes toward siting a potentially hazardous facility. Two telephone surveys undertaken in early 1987, a national sample of 1,201 U.S. households, and a sample of 1,001 residents of Nevada, examined risk perceptions and attitudes toward the repository. Only data for the Nevada sample are reported here, as the findings from the national sample are extremely similar. The survey was designed to determine the role of various perceptual and attitudinal factors on residents' WTA a high-level repository at Yucca Mountain. Respondents were asked whether or not they would vote in favor of a repository under the condition that an annual federal tax credit would be provided over the next 20 years. The rebate was equal to either $1000, $3000 or $5000, depending upon the experimental condition to which the respondent was assigned.\(^1\)

The empirical analysis that follows investigates how accurately an expected utility model is likely to characterize individuals' attitudes toward voting for a repository. What risk-related factors explain willingness to vote (VOTE) for or against a repository? How sensitive are voting preferences to variations in the rebate level?

To answer these questions, we constructed a logit model in which the probability that a person would vote for a repository is a function of a set of independent variables. Duncan Luce and Patrick Suppes (1965) have shown that a logit model is a strict utility model such as (2), under the assumption that the random component of this probabilistic choice model is independent and identically distributed. Analyses of the data indicate

\(^1\)This elicitation procedure is a type of referendum model. Robert Mitchell and Richard Caron (1989) have made a strong case for using this type of procedure in contingent valuation surveys.
that socioeconomic characteristics are not statistically significant in explaining VOTE so these factors are not included in the models presented below.\footnote{For more details on these findings as well as comparisons between the Nevada and national surveys, see Kupe and others (1988).} The present analyses are based on 470 respondents who responded to the WTA question, and focus solely on how risk-related variables and different rebate levels affect intended voting behavior.\footnote{A willingness-to-pay question was substituted for the WTA item for 503 respondents. In addition, 28 of those asked the WTA item responded “Don’t Know” and were omitted from these analyses.}

**Impact of Risk-Related Factors.** With respect to measuring risk perceptions, we utilized two types of variables: (i) proxies for probability and consequences, and (ii) more subjective factors related to risk perceptions. With respect to (i) the variables are the probability of an accident at the repository (PR-ACCD), the probability that repository wastes will leak into the groundwater (PR-WATER), the belief that a repository accident would involve certain death (CONS-DEATH), and the belief that an accident would kill many people at the time (KILLMANY).

Model 1 of Table 1 presents the results. As expected, those individuals who perceive the probability and consequences to be relatively high are more reluctant to vote in favor of the repository at Yucca Mountain. For the $1000 rebate condition, an individual with the most pessimistic values on all four risk predictors has an estimated probability of voting yes equal to .071, while for an individual with the most optimistic values on all four, the estimated probability is .824.

Model 2 of Table 1 examines the incremental effect of four subjective risk measures under category (ii). Each of these measures was found to be statistically significant controlling for perceptions of probability and consequences.

The TRUST variable refers to the respondent’s belief that the federal government will safely manage the repository. The sensitivity of VOTE to this factor suggests that for facilities where there is considerable uncertainty regarding the scope of the risk, individuals rely on the credibility of those agents who are seen as controlling the risk.

Our ability to predict VOTE is also enhanced by including two of the subjective risk features identified by Paul Slovic (1987) in the model. CONTROL and DREAD, respectively, represent the respondent’s belief that nearby residents can control the risks of a repository, and that the facility will be dreaded by residents. These two features correspond to the impact of risk exposure per se, rather than the statistical expectation of a low event. Their significance in explaining VOTE suggests that the anticipation of a repository will be anxiety provoking; thus, the benefit package $B$ will be offset some.
The size of the RISK-FUTURE effect indicates that individuals tend not to discount the future consequences of nuclear waste storage (where the effects are expected to endure for up to 10,000 years), perhaps because of the irreversible features associated with storing high-level radioactive waste in the repository. Confirming evidence on the treatment of future generations comes from a recent study by Ola Svenson and Gunnar Karlsson (1989) who found that a sizeable number of individuals are reluctant to discount to the present the future losses associated with nuclear waste disposal.

Rebate Level. Contrary to our expectations, we found no statistical evidence that preference for the repository differed as a function of the dollar value of the annual rebate. The proportion voting in favor ranged only from 28 to 32 percent across the three levels of $1000, $3000, and $5000 per year.

This finding suggests that the increased acceptability of a repository due to rebates is captured almost entirely in the change from $0 to $1000; the next $4000 in compensation elicits no additional support. Such a result is consistent with a threshold model of choice, whereby individuals refuse to consider compensation if the perceived risk falls in an "inadmissible" range. For those respondents where the risk was perceived to be too high, the rebates offered were viewed not as inadequate, but as inappropriate. Given the large proportion of individuals who opposed the repository even at a $5000 annual rebate, it appears that most of the Nevada sample viewed the risks as inherently noncompensable, at least when the benefits are in the form of direct payments to individuals.

III. Discussion

The results suggest that compensation in the form of a rebate is unlikely to have a positive effect on siting a potentially hazardous facility, unless the risk is perceived to be sufficiently low to oneself and to others, including future generations. In the case of nuclear waste facilities, benefits are simply rejected out of hand unless the safety of the facility and the integrity of the siting process are assured (Elizabeth Peele and R. Ellis,
1987; Richard Bryan, 1987). This conclusion does not mean that tradeoffs between risk and benefits are inappropriate when it comes to siting hazardous facilities. Rather it suggests that before one attempts to initiate this process, some threshold level of safety to nearby residents must be assured.

Further, it is clear from the analyses that residents will be confident that the risks are low only if they trust the agencies responsible for constructing and operating the facility; standard risk assessments proffered by experts will not be sufficient. The indispensability of this public confidence was recently recognized by Department of Energy Secretary James Watkins when he abandoned the existing repository planning effort in Nevada. Although these studies had taken two years and cost $500 million, scientific disputes regarding the integrity of the data had fueled effective public opposition to the Yucca Mountain site (Matthew Wald, 1989). The decision delays until at least 2010, and probably longer, the opening of a repository at Yucca Mountain.

REFERENCES


Smith, V. Kerry, “Can We Measure the Economic Value of Environmental Amenities?,” Presidential Address to Southern Economic Association, 1989.
