Environmental Valuation with Imperfect Information: The Case of the Random Utility Model

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1 Introduction

Consumers rarely have perfect information about the quality of the goods that they purchase, and they are often forced to make consumption decisions in partial ignorance. With the classical experience good, for example, quality is at least partially unobservable at the time of purchase. After consuming the good, the individual observes its true quality, and his utility will be a function of this true quality. Thus, although purchase decisions are influenced by *perceptions* of quality, the consumer's *ex post* utility is determined by *true* quality. In this paper, I argue that environmental quality is often similar to the classical experience good, and efforts to value changes in environmental quality without taking this into consideration will result in welfare estimates that are incorrect.

The driving force behind the voluminous environmental valuation literature over the past three decades has been the desire to measure the welfare effects of changes in environmental quality (see Freeman, 1993; or Cropper and Oates, 1992). This literature has for the most part abstracted from information issues, and quite understandably.[2] After all, the obstacles to obtaining utility theoretic welfare measures have proven to be quite daunting (Bockstael and McConnell, 1999). However, with nonmarket environmental goods in particular, the assumption

[2] This is not to say that the problems associated with inaccurate perceptions have been ignored entirely. Several studies explore the role of perceptions within the context of environmental valuation (e.g., Taylor et al., 1999; Adamowicz et al., 1997; Bockstael et al., 1988; Bouwes and Schneider, 1979; Binkley and Hanemann, 1978). But the general approach has been to *compare* perceptions of quality to objective measures of quality or to *compare* welfare estimates using only perceptions of quality to welfare estimates using only objective measures. Although these comparisons provide a general feel for how far off we will be when we incorrectly assume that information is perfect, they ignore the fact that when perceptions of quality are wrong, the standard techniques for welfare measurement must be amended.

that perceptions of quality are correct is troubling, and it is arguably the rule rather than the exception for consumers to "purchase" environmental quality when information is imperfect. Swimmers will commit to a lengthy drive to the beach with only limited knowledge about water quality, hunters will drive several hours to a hunting site after hearing rumors of plentiful game, and home buyers will close on a house with no more than a rough idea about neighborhood air quality. In contrast, the quality of marketed goods is often easier to ascertain prior to purchase: tires are kicked, fruit is examined, and clothes are tried on.

Yet the standard practice for researchers using behavioral techniques to value changes in environmental quality is to assume that information is perfect and individuals' perceptions of quality are correct. Because these perceptions—rather than objective, scientific measurements of quality—are what ultimately determine choices, standard welfare estimates derived from these choices will be incorrect when perceptions are wrong. This paper will examine the implications for environmental valuation when perceptions of quality differ from true quality. I focus on the random utility model, a popular and utility theoretic approach to modeling choice, and a model often used in environmental valuation. With the exception of Foster and Just (1989), who confine their attention to the quality of a marketed good, previous attempts to apply welfare analysis to environmental quality changes under imperfect information have been incomplete.

A brief, intuitive discussion of the difficulties that arise when perceptions are incorrect will clarify the more formal results that follow. Consider the random utility model, where the consumer faces a choice from a set of mutually exclusive alternatives. Let the vector b represent the objective levels of quality associated with each alternative, and let the vector b^* represent the consumer's perception of those qualities prior to making his choice. In the choice of beaches, for example, b might represent water clarity as measured by natural scientists, while b^* might represent the consumer's perception of water clarity prior to the visit.

There are essentially two types of complications that arise when perceptions of quality are incorrect. The first complication involves estimation. When $b^* \neq b$, the parameters of the preference function estimated by the researcher using data on b will be biased. In choosing from among the set of alternatives, the individual maximizes a utility function that depends on b^* rather than b. Although the utility received by the individual *ex post* may be a function of true quality, his *ex ante* decisions (which are used to estimate the preference function parameters) are a function of perceived quality.[3] The researcher will only be able to recover the parameters of the preference function in cases where $b^* = b$ or in cases where it is possible to actually measure b^*. The former may be true when environmental quality has been stable for a long period of time, so that individuals have had ample opportunity to revise incorrect perceptions through experience. The challenges associated with the latter approach are well known and discussed extensively in the contingent valuation literature (see Mitchell and Carson, 1989).

The second complication arises after these estimation difficulties have been overcome, and the researcher turns to the task of calculating welfare measures. Suppose that perceptions are perfectly in line with true environmental quality, so that the researcher is able to estimate the parameters of the individual's preference function. In assessing the benefits of a proposed environmental regulation, the next step is to use this function to calculate the compensating variation associated with a hypothetical change. The traditional approach is to assume that the individual will have perfect information after the change. But changes in environmental quality are far from transparent. When post-change perceptions of quality are incorrect, individuals' consumption choices will also be incorrect (in the sense that they will differ from choices made under perfect information). Although consumers may benefit from an improvement in quality, they will benefit less than they would if they were perfectly informed and could make optimal choices. As a result, the traditional welfare measure will be biased.

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[3] Of course, there are situations—especially those related to health rather than aesthetic impacts—where the consumer does not know quality even *ex post*. For example, a beachgoer may experience the negative health effects of bacterial contamination without recognizing the link to swimming in polluted waters (see Ibáñez, 1999). Furthermore, in many choice situations, quality will be stochastic and perhaps more appropriately characterized by a vector of distribution parameters (Foster and Just, 1989).

If perceptions of environmental quality are indeed wrong, then there will be value to providing information about environmental quality *even if true quality is held constant.* It would be useful to be able to measure an individual's willingness-to-pay to move from a situation where $b^* \neq b$ to a situation where $b^* = b$, holding true quality constant. For example, the United States Environmental Protection Agency maintains an internet site that provides information about the environmental quality at beaches across the country.[4] Such public information campaigns are not without cost, and estimates of the benefits associated with the provision of such information would be informative.

After briefly reviewing the literature, I derive a measure of the benefits of a change in environmental quality within the random utility model framework when perceptions of quality are allowed to be incorrect both before and after the change. This welfare measure is a generalization of the measure developed by Small and Rosen (1981) and Hanemann (1982); it reduces to the traditional measure when perceptions of quality are correct. An illustrative application to moose hunting is then presented, and welfare estimates are obtained for hypothetical changes in quality and information.

2 Literature Review

Data on perceptions of environmental quality are difficult (and expensive) to obtain, and the paucity of studies addressing the issue reflects this difficulty. It is much easier, for example, to obtain data on water clarity from a government agency than it is to *ask* swimmers about their perceptions of water clarity. Even if they could successfully state their true perceptions (which is questionable), different individuals will have different subjective scales of measurement. So although few economists would deny that perceptions are the basis of choices by individuals,

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[4] www.yosemite.epa.gov/water/beach/nsf

only a handful of studies devote significant effort to exploring the issues that arise in valuing environmental quality changes when perceptions are incorrect.

Swartz and Strand (1981) examine the welfare losses caused by a contamination "scare" when consumers have imperfect information about quality. They provide estimates for the losses incurred when consumers shift consumption away from a good that is wrongly believed to be contaminated. In this case, the true quality of the good remains constant, but perceptions of quality decline, and consumers suffer welfare losses when they alter consumption choices to avoid the good. Swartz and Strand use changes in Marshallian consumer surplus to measure welfare losses. This approach overestimates welfare losses, since consumers do not actually experience the adverse health effects implied by the lower demand curve during the contamination "scare."

Foster and Just (1989) suggest an alternative approach—an approach that allows perceptions to influence purchase decisions while allowing true quality to influence *ex post* utility. Although they focus on the quality of a marketed good (the empirical application is to a milk contamination event in Hawaii), the conceptual approach that they develop is directly applicable to non-market valuation methods. Among other things, they are able to successfully measure the value of information about quality, which in their case is equal to the losses that consumers incur when a public agency withholds information about a contamination event. Prior to the event, consumers are assumed to have correct perceptions of quality, b^0.[5] After the event, perceptions of quality remain constant at b^0 and consumers continue to purchase the good, but true quality has declined to b^1. The authors suggest the following measure of the welfare effect of the change in quality:

$$(1) \qquad cv = \tilde{e}\left(p,u,b^0;x^0\right) - \tilde{e}\left(p,u,b^1;x^0\right) = e(p,u,b^0) - \tilde{e}\left(p,u,b^1;x^0\right)$$

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[5] Foster and Just assume that quality is random and can be represented by a vector of distribution parameters. In order to simplify the explanation, I allow quality to be deterministic. In addition, Foster and

Here, p is the price of x, the price of the numeraire, y, is unity, and $\tilde{e}(.)$ is a restricted expenditure function defined by

$$(2) \qquad \tilde{e}\left(p,u,b,x^0\right) = \min_{x,y}\left\{px + y : x = x^0,\ u(y,x,b) \geq u\right\},$$

and x^0 solves the unrestricted expenditure minimization problem,

$$e\left(p,u,b^0\right) = \min_{x,y}\left\{px + y :\ u(y,x,b^0) \geq u\right\}.$$

Thus, utility is allowed to depend on the true quality of the good (the second restriction within the brackets in expression (2)), but the quantity chosen is restricted to x^0, the quantity that would be selected under perceived quality (the first restriction within the brackets).

In what is perhaps the first extension of the Foster and Just methodology to the non-market arena, Ibáñez (1999) estimates the value of information about water quality to beach users in Colombia. She separates water quality into an aesthetic component, which is observable during the beach visit, and a health component, which is unobservable during the visit. Individuals are classified as "informed" or "uninformed" with respect to the health component of quality according to their responses to survey questions. She estimates a random utility model of beach choice, and she calculates the value of providing information to the uninformed individuals about the potential health effects of water contamination.

Although not necessarily concerned with environmental valuation, the risk perceptions literature has devoted great effort to understanding how perceptions of quality (or risk) are formed and updated (Viscusi, 1997; Smith et al., 1990; Smith and Johnson, 1988; Viscusi and O'Connor, 1984). The approach in this literature is to assume that a Bayesian learning process is operative: an individual holds prior beliefs about risk, and the individual's experiences provide new information that allow him to update this prior. Survey techniques are used in controlled experiments where respondents are questioned about their prior risk beliefs, given new

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Just's notation implies that compensating variation for a decline in quality would be positive. I reverse information, then questioned about their posterior risk beliefs. Empirical implementation has typically involved a linear regression of posterior risk perception on prior risk perception and on some measure of the magnitude of risk implied by the new information. Again, despite providing considerable insight into how perceptions form and evolve, the focus in these studies is on the *process* of perception formation rather than on the implications for valuation when perceptions are incorrect.

In a recent paper, McCluskey and Rausser (1999) provide a link between the risk perception literature and the environmental valuation literature by embedding a model of perception formation within a hedonic property value model. They specify a hedonic price function that has perceived risk (from a nearby hazardous waste site) as one of the arguments. Risk perceptions are assumed to evolve in a Bayesian manner, with current perceived risk a function of prior risk perception and recent media information. Generalized maximum entropy techniques are applied to a panel data set to recover the parameters and the unknown state variable (perceived risk) in the model. Because McCluskey and Rausser lack data on objective risks from the hazardous waste site, they are unable to explore the welfare implications when housing *choices* are determined by risk perceptions but health *outcomes* are determined by actual risk.

3 Welfare Analysis with the Random Utility Model Under Imperfect Information

The purpose of this section is to derive a welfare measure for a change in environmental quality within the random utility model framework when perceptions of quality are incorrect. For the present, I abstract from problems of estimation. That is, I assume that the researcher is able to estimate the utility function successfully either by obtaining data in a period when individuals are correctly informed about quality (for example, after site qualities have been constant for a

their notation to maintain consistency with the convention in Just, Hueth, and Schmitz (1982).

considerable length of time), or by obtaining data on perceptions of quality. I also assume that environmental quality is an experience good. That is, although choices are based on perceptions of quality, the objective level of quality is perfectly observable after the good is consumed, and the consumer's utility is a function of this objective quality.

3.1 The Random Utility Model Under Perfect Information

Suppose for the moment that perceptions of quality are correct. As in the traditional random utility model (McFadden, 1974), assume that individual i chooses a single unit from among N mutually exclusive alternatives in his choice set, S_i. Upon selecting alternative j, indirect utility is given by

$$v_j(y - c_j, x_j, b_j) + \varepsilon_j = v_j + \varepsilon_j, \tag{3}$$

where y is the income available for the choice occasion, c_j is the cost of alternative j, x_j is a vector of observable characteristics associated with alternative j, b_j is the objective level of quality associated with alternative j, and ε_j represents the effect of characteristics of alternative j that are observable to the individual but unobservable from the researcher's perspecive (subscripts associated with the individual are omitted for simplicity). The consumer will choose alternative j when

$$v_j + \varepsilon_j \geq v_r + \varepsilon_r \qquad \forall r \in S.$$

If the ε are independently and identically distributed as type I extreme value (or Weibull), then the probability that site j maximizes utility is given by

$$\pi_j = \frac{\exp(v_j)}{\sum_{r \in S} \exp(v_r)},$$

and a likelihood approach can be used to estimate the parameters of v_j. Let d_{ij} be a dummy variable equal to one if individual i chooses alternative j and zero otherwise. If Q individuals are observed making independent choices, the likelihood function can be written as