Option value - improving resource allocation efficiency

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CHAPTER 1

Introduction

Measuring consumer benefits associated with a policy or a project in a world where prices and outcomes are known with certainty is, at least in theory, straightforward. Changes in consumer surplus provide an appropriate measure of a policy's contribution to consumer welfare. But, in a world where prices and outcomes are uncertain, there is a strong case for concluding that measuring expected consumer surplus alone is inadequate (Bishop, 1982), and in many natural resource situations, uncertainty is the rule rather than the exception. Option value is the adjustment, if any, that is made to expected consumer surplus when there is uncertainty about the demand or supply of an environmental asset.

The concept of option value is based on Weisbrod's (1964) argument that consumers, uncertain about their future demands for a commodity, would be willing to pay something above expected consumer surplus to maintain an option to consume the commodity in the future. As we have noted, this additional "payment" is option value. While Weisbrod's argument suggests that option value is positive, this need not be the case. A variety of authors have proven that option value can take either sign, depending on the specific circumstances, and especially on the type of uncertainty involved.

Empirical studies have shown that option value may be as great as half expected consumer surplus (Fisher and Raucher, 1984), indicating that the concept has great significance in determining the optimal allocation of resources. Given the magnitude of option value identified in empirical studies, and its ambiguous sign, serious misallocations are likely to occur if it is not understood and accounted for. In particular, the existence of uncertainty implies that current evaluation procedures, such as cost-benefit analysis, that rely largely on expected values, can be inappropriate and may provide misleading information. This publication seeks to improve the understanding of option value so that New Zealand resource management agencies can formulate appropriate decision-making and impact-evaluation policies under conditions of uncertainty, and better identify desirable outcomes under conditions of uncertainty.

We begin with an overview of the origin of option value in economics and its relevance to decision making under uncertainty. The next chapter considers compensation tests and identifies an *ex ante* compensation test as being appropriate for uncertain situations. Option value is then located within a total value framework that includes use values and existence values. Uncertainty in both demand and supply is then shown to provide justification for considering option value as an adjustment that individuals make to allow for uncertainty. However, we will show that there are few situations where the sign of option value can be unambiguously established in theory. The final chapters of the publication describe how option value can be measured and incorporated into cost-benefit analysis.

CHAPTER 2

Background

Friedman (1962) identified market imperfections (e.g. monopoly) and neighbourhood effects (e.g. pollution) as two situations that might necessitate government action in a market economy. Sufficient justification for government action was shown to arise when strictly voluntary exchange was technically impossible or exceedingly costly. The example he considered, the supply of parks, has obvious relevance to this publication. In the case of a central city park, Friedman suggested that it would be very expensive to collect a fee from individuals benefiting from the park so as to finance supply. In contrast, he thought that it would be technically feasible, and less expensive, for private enterprise to set up toll gates at the entrance to a large remote national park (e.g. Yellowstone National Park) to collect a fee from visitors.

> "If the public wants this kind of activity enough to pay for it, private enterprises will have every incentive to provide such parks" (p.31).

Furthermore, in the case of Yellowstone National Park he could not:

> " ... conjure up any neighbourhood effects [externalities] or important monopoly effects that would justify governmental activity in this area" (p.31).

Friedman's choice of a national park and a central city park illustrates the importance of describing the dimensions of a good in detail beyond a simple public-good, private-good, dichotomy. Although both parks supply services with "public good" characteristics only the central city park, in Friedman's opinion, requires use of the coercive mechanisms of government. Demand-side uncertainty exists in both cases. Individual users of the services in each park would not be able to predict their future demand with certainty. In contrast to users of the national park, the population of central city park users would be more concentrated and individuals' use patterns would tend to be less planned, spontaneous and frequent. Supply-side uncertainty can arise from the inherent variability of the natural system (e.g. the lack of snow affecting skiing in the national park) and the decisions of public agencies (e.g. city government reducing the facilities in the central park).

Friedman concludes that economics does not provide precise guidance as to the boundary between private and government activities in the economy.

> "Our principles offer no hard and fast line how (sic) far it is appropriate to use government to accomplish jointly what it is difficult or impossible for us to accomplish separately through strictly voluntary exchange" (p.32).

The problem considered by Friedman belongs to the genre of public (collective) goods. For many goods it is not possible to classify them simply on the basis of the private-public dichotomy. If a good, purchased for individual consumption, contains elements of a collective good then there is a possibility that the quantity produced is not optimal. The corollary that often follows this proposition is that if private enterprise cannot profitably provide the good then social wellbeing might be enhanced by public sector supply.

Weisbrod (1964) offers two reasons why private provision might diverge from optimal social provision. First, some commodities are purchased infrequently and demand is uncertain. Second, the cost of increasing production once production has ceased, or curtailed, might be relatively high or technically impossible. Although these two characteristics apply to many natural environments, such as national parks, indigenous forests, wildlife habitats and water resource systems, they may also apply to produced goods such as hospital services, art collections, historic places, and urban transport systems.

With these two characteristics in mind, Weisbrod considered Friedman's example of a national park where it is easy to charge a fee, the park is privately owned, the firm can price discriminate, the good is not storable and there are no external economies. If total cost exceeds total revenue, then it is profitable for the firm to close the park and allocate resources into other uses. Weisbrod notes that the decision to close the park might not be socially optimal because:

> "... people who anticipate purchasing the commodity at sometime in the future, but who, in fact, never will purchase it ... they will be willing to pay something for the option to consume the commodity in the future" (p.472).

Weisbrod defined option demand as a person's willingness-to-pay for an option to consume the commodity in the future, even if the individual is not a current user and never actually exercises the option. Economic efficiency requires consideration of both user willingness to pay and option demand. In theory, option demand should influence supply but the lack of a practical non-coercive mechanism by which the firm can collect a fee from non-users, or the option value over and above the willingness to pay associated with current use, means that these preferences will not be considered by the profit-seeking firm. Therefore, if total revenue is not sufficient to cover total costs, the firm will either seek to adjust its operation to lower costs or it will close down.

The two extremes of supply can be considered as a binary variable:

$\alpha = 0$ the park remains open, or
$\alpha = 1$ the park closes

If $\alpha = 0$ then option demand is satisfied, however, the problem of getting consumers to reveal their preferences remains. If $\alpha=1$ resources of the private firm will be reallocated, perhaps into mining the land. In the extreme, if the site is developed and the natural beauty of the area irreversibly lost, then the opportunity cost of an option to enjoy the park in the future is positive, provided of course that at least one individual attached a value to the park.

The supply of current services associated with the park enters the utility functions of two groups of individuals. Those using the park express their preferences by actually visiting the site and enjoying its benefits. Revenue from charging for access, as is the case in numerous parks throughout the world, provides at least a preliminary estimate of aggregate value. However, continued supply also enters the utility functions of current users and prospective non-users and collecting a fee from them would be expensive.

Friedman's early challenge of the conventional wisdom regarding supply of collective goods and Weisbrod's suggestion that option value should be accounted for in supply decisions, raised some difficult theoretical issues for public sector decision making. Environmental economists were quick to recognise the significance of option value when considering choice where some decisions would have irreversible adverse consequences. They were sceptical of the allocative efficiency of the market mechanism and their conclusions supported the observations made earlier by Weisbrod. Krutilla (1967) illustrated the difficulty that option value poses for project evaluation when irreversibilities exist. Even if perfect price discrimination is feasible, receipts under private ownership are not comparable with estimates of willingness to pay derived from use values. When evaluating alternative actions within an efficiency framework, attention must be given to obtaining estimates of both use-related willingness to pay and use, use-related option value and non-use related option value. For the profit-seeking organisation the practical problem of appropriating non-user values remains. At the time, private non-profit organisations, such as the Nature Conservancy, were active in the preservation market but, as Krutilla suggested, the market is imperfect and does not provide an accurate guide to total value.

Introducing time into the analysis, within a cost-benefit framework, brings into focus the difficulties posed by the dynamics of option value. It is becoming evident, in some forms of recreation at least, that participation today stimulates demand in the future (Davidson *et al.,* 1966). For example, an individual with no history of using a park at time t might be willing to pay nothing for an option for future use. However, it is quite conceivable that at time $t + h$ this individual will be exposed to the enjoyment others derive from use which in turn encourages either use at $t + h$ or results in a positive willingness to pay for an option for future use at $t + k$ where $k > h$. That is, there is an interaction between present demand, future demand and option demand.

The original work in the 1960s of Friedman, Weisbrod and Krutilla, set the stage for research into the theoretical underpinnings of option value, the development of practical valuation methods, and a reconsideration of cost-benefit analysis under conditions of uncertainty. In subsequent chapters of this publication, we survey the research completed on these topics, and report on the results to date.

CHAPTER 3

Cost-benefit analysis and uncertainty

The task of the cost-benefit analyst is to specify demand functions representing societal willingness to pay, and supply functions representing social marginal cost, in order to identify efficient allocations of resources. To complete this task, to a reasonable degree of accuracy, requires an understanding of the theoretical constructs that underpin cost-benefit analysis. In particular, the conditions of demand and supply need to be specified, and estimates made of these concepts, in a way that is consistent with the compensation tests used to identify efficient allocations. Concern for uncertainty and time are two characteristics endemic to most natural resource problems. In this chapter we review the means by which time and uncertainty are incorporated into the cost-benefit framework.

In an economic system goods and services flow from producers to individual consumers who use goods for their needs. Each good, measured in appropriate units (e.g. tonnes, cumecs), is characterised according to its quality, location, and the date of availability (Malinvaud, 1972). Some goods will be divisible, others not. If a good is divisible, then each unit is assumed to be identical, i.e. goods are homogeneous. Two quantities of the same good, equal in all respects other than location, can be treated as different goods. For many classes of commodities it may also be important to assume a finite number of locations. For example, many services associated with a national park are not transportable; an aquifer supplying community drinking water would have a finite boundary, although the recovered water would be transportable. Finally, two equal quantities of the same good, say drinking water, available at different times are different goods. In summary, the demand and supply of a good is defined over three dimensions: quality, location and time.

It is traditional to classify goods according to a continuum bounded at two extremes by private and pure public goods. Private goods have the characteristic that individual consumption of the good precludes another person's consumption. Total consumption of a divisible private good Q_j is simply the sum of consumption over m individuals:

$$Q_j = \sum_{i=1}^{M} Q_j^{\,i} \qquad (1)$$

In contrast, public goods have the characteristic that each person's consumption of the good does not lead to a subtraction of any other individual's consumption. Total consumption of the pure public good Q_k is:

$$Q_k = Q_k^{\,i} \quad \forall i \qquad (2)$$

Pure public goods are characterised by non-excludability and non-rivalness in consumption. An ability to exclude non-paying consumers from enjoying the benefits of supply is necessary for private sector supply. The cost of exclusion is determined by technical feasibility and the price of inputs necessary to exclude non-paying consumers. Non-rivalness in consumption arises from indivisibility of the product and results in the marginal cost of an additional consumer being zero. If a good is non-excludable, then there is no incentive for profit-seeking producers to supply the good. However, simply because a good has public good characteristics is not sufficient justification for public sector production. Numerous activities can be financed by the public sector but produced by private firms, and the cost of supply may be greater than aggregate benefits.

Economic systems are characterised by their endowment of natural resources, technology, institutions and the flow of goods and services. Reallocating resources, under conditions of scarcity, involves an opportunity cost. For example, it might be possible to lower nitrate levels in ground water (improving water quality) by regulating fertiliser use in agriculture. Households using the aquifer for water supply would benefit from reduced contamination. In the absence of compensation, at least one person (presumably a farmer) would be disadvantaged by the regulation. The rationale for applying the cost-benefit framework in this example is to identify alternative states of the world (levels of water quality, given certain regulations) where it is theoretically possible for the "gainers" to compensate the "losers". This potential compensation test, known as the Hicks-Kaldor compensation test, provides the welfare theoretic basis for applied cost-benefit analysis.

In a certain environment, each individual knows the quality of the environmental resource (Q) at time t_o, the future state $Q(t_{0+h})$ and the time path of Q during the intervening period. Under conditions of certainty, each individual knows how his/her utility, or profit, would change as a result of policy. The compensated variation of the gainers is defined as the largest sum they would be willing to pay (WTP) to enjoy the end-state (e.g. at $Q(t_{0+h})$ = improved water quality) associated with the policy at each point in time. The compensated variation of the losers is the least sum they would be willing to accept (WTA) to live willingly in the end state (e.g. at t_{0+h} profit is lower because of regulated land management practices) implied by the project. A potential Pareto improvement is identified when aggregate benefits (ΣWTP) exceed the costs (ΣWTA). It should be noted that compensation is purely hypothetical and there is no presumption that compensation is actually paid.

Competitive markets in the absence of externalities produce prices that can be used as a measure of the benefit to consumers. Many cost-benefit analyses assume that individuals express their preferences through a pricing mechanism operating in a certain environment. Therefore, the conditions surrounding the demand and supply of a good Q is assumed to be known with certainty - there is only one possible state of the world {S}. To incorporate uncertainty into cost-benefit analysis, each individual in the economy is assumed to make decisions in the knowledge of the set of possible states (Arrow, 1964). There are assumed to be S possible states of the world, $s = 1,...,S$. In the s^{th} state, Q_s is the amount of commodity Q available. Uncertainty is also concerned with the future and, in principle at least, there exists a set of possible states at each point in time $\{S|t\}$.

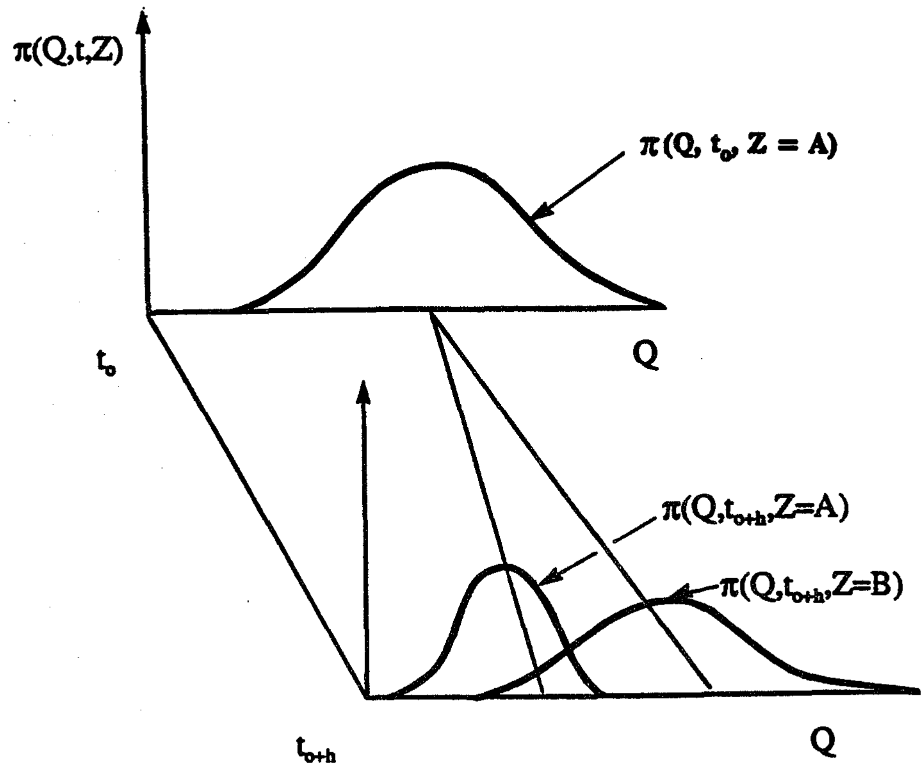

Figure 3.1 **Uncertainty and time.**

In a world of perfect information, where knowledge of $\{S|t\}$ is available to all, each individual i will attach his/her own vector of subjective probabilities $\pi_i = (\pi_{i1},...,\pi_{is})$ to the set of possible outcomes in each period. This is illustrated in Figure 3.1 by a probability distribution π describing possible Q at each point in time. To avoid the problems of imperfect perceptions of risks it is usually assumed that the probability of each state occurring is agreed to by everyone, that is $\pi_i = \pi_j \ \forall i,j$. In practice it seems likely that information on $\{S|t\}$ is asymmetrically distributed among individuals before their subjective probabilities are attached to each possible state, hence it is possible that $\pi_i \neq \pi_j$.

Consider, once again, a community that draws water from an aquifer threatened by the prospect of nitrate contamination. Nitrate concentration, expressed in ppm, is given by Q; Q_s is therefore a specific concentration (say 15 ppm) occurring in a given state. For example, $Q_s=15$ might be consistent with a policy option that regulated the quantity and timing of nitrogen application to crops. Given the natural variability inherent in water resource systems, the probability of $Q_s=15$ would be specified by π_s. In environmental systems, changes in the supply of Q are rarely instantaneous. More often than not there is a lag between an action (such as reducing nitrogen application rates) and observable changes in nitrate concentrations. This means that each uncertain state of the world is also a function of time. Using $\pi(Q,t,Z)$ to describe the probability distribution of groundwater quality, Figure 3.1 shows how different policy actions (Z = A,B) at t_0 result in different probability distributions of Q at t_{0+h}. The analyst is now confronted with the task of incorporating both uncertainty and time into the analysis.

Attempts at incorporating the twin problems of uncertainty and time into cost-benefit analysis have centred on adjustments to the discount rate and the basis of the compensation test itself. Let's consider the discount rate first. It is generally accepted that individuals are influenced by uncertainty and will not value outcomes at their expected values. This behaviour is evident in capital markets where individuals do not necessarily maximise the present value of expected returns; rather, they maximise the present value of returns adjusted for risk. Hirshleifer (1965, 1966) argues that investments in perfect capital markets are properly discounted with respect to both time and risk and these discount rates should be used in public policy analysis. Some economists have argued that uncertainty can be allowed for by adjusting the discount rates attached to the flows of benefits and costs over time (Eckstein, 1965). The analysis of others, such as Arrow and Lind (1970), suggests the use of a riskless discount rate. Both Hirshleifer and Arrow and Lind assume that individual preferences are relevant for public decision making and that these preferences should provide the basis for valuing benefits and costs. The Arrow-Lind result of a riskless discount rate depends on an assumption regarding the ability of governments to spread the risk of public sector decision making among a large number of people.

More recently the approach of adjusting the discount rate has been challenged by those who consider that the analysis should focus directly on the compensation test itself. Starting with individual valuations of each possible state of the world, Graham (1981) concludes that aggregate willingness to pay in each state is the appropriate measure of benefit. The implication is that a riskless discount rate should be used along with the price (contingent prices) individuals attach to each possible state of the world. In other words, the influences of uncertainty on WTP/WTA is measured directly through the (contingent) pricing mechanism and not through *ad hoc* adjustments to the discount rate. If the argument for a riskless discount rate is accepted then the appropriate compensation test needs to be carefully considered because uncertainty affects the distribution of costs and benefits and efficiency through its effect on the costs of risk bearing (Ulph, 1982).

Returning to Figure 3.1 for the moment, the individual is confronted with a probability distribution of outcomes $\pi(Q,t,Z)$. Figure 3.1 shows uncertainty at t_0 using two different probability distributions associated with policy actions A and B. While it should be recognised that different policies can conceivably produce different probability distributions over time, this adds an unnecessary degree of complexity to the exposition at this stage. Two compensation tests can be applied to uncertain situations where a riskless discount rate is used. One test (*ex ante* compensation) uses an *ex ante* perspective based on what the individual expects to receive/pay **before** knowing what the state of the world will be. Individual valuations are made at t_0 on the basis of $\pi(Q,t, Z = A)$. The individual knows that option A will be implemented but does not know what Q will be. Option price is the *ex ante* state independent of WTP for a specified change ΔQ (Mitchell and Carson, 1989). The notion of state independency is rationalised on the basis that decisions made now (say at t_0) and individuals' payments for the predicted change (ΔQ) rarely depends on what actually happens at t_{0+h} (say, e.g., $\Delta Q'$). For example, it might turn out that water quality is improved above the predicted level, $\Delta Q' > \Delta Q$. The *ex ante* test examines whether the aggregate WTP (option price) of *ex ante* gainers exceeds the WTA of *ex ante* losers (option price).

The policy passes the test if ΣWTP > ΣWTA. A distinguishing feature of the *ex ante* test is that when the policy is undertaken, and a **particular** outcome occurs, some individuals **will** be worse off.

The other test (*ex post* compensation) uses an *ex post* perspective based on what the individual expects to receive/pay **after** knowing what the state of the world will be. Hence, an *ex post* measure of WTP is based on the consumer surplus in the state of the world **as if** that state occurred. Policy A would pass the compensation test if the gainers could compensate the losers in **all** states of the world (Bishop 1986). Continuing with the example, an *ex post* valuation of the benefits would be based on the change in consumer surplus associated with $\Delta Q = Q\ (t_0, Z = A)\ \text{-}Q\ (t_{0+h}, Z = B)$. In practice, expected consumer surplus is measured only in the state of the world that did occur. For example, the travel cost method used by Kerr *et al.* (1986) to measure the benefits of Mount Cook National Park provides an estimate of the expected consumer surplus that occurred during the year in which the study was undertaken.

When a policy is implemented it is possible that the state that **actually** occurs results in ΣWTA>ΣWTP. That is *ex post* the policy would not be recommended on efficiency grounds. It is at this point in the argument that the Arrow-Lind result is significant because they envisaged government financing the risk of this outcome, via the tax system, over all taxpayers so that the with-tax liability of each individual is negligible. Therefore, *ex post* compensation eliminates the specific risk borne by individuals. Results following from the Arrow-Lind proposition assume that outcomes are expressed purely in terms of financial risk where (risk-averse) individuals can take out insurance against adverse outcomes. In fact this is the basis of *ex post* compensation where each individual loser is fully reimbursed either through voluntary (market) transactions or through government guarantee.

There is increasing weight of argument now that the *ex ante* compensation test is more appropriate in uncertain situations (Graham, 1981; Ulph, 1982; Bishop, 1987; Smith, 1987a). This is because the *ex ante* test can handle a greater array of economic variables which influence the adjustments that individuals explicitly make to their valuations to allow for uncertainty. The adjustment is option value. Furthermore, if policy makers accept the principle of consumer sovereignty then it behoves analysts to identify and, if possible, incorporate the valuations of individuals into analyses of policy options.

Risk and uncertainty have long been recognised as difficulties facing cost-benefit analysts. A range of techniques has been devised to tackle risk and uncertainty insofar as it relates to parameter values. A simple and widely noted method is to ensure that sensitivity tests are completed and reported in the cost benefit study. Sensitivity tests operate when the analyst varies the values employed for certain parameters, and recalculates the appropriate benefit and/or cost figures. This process can be repeated as many times as the analyst wishes and in each case the new results can be compared with the results from the 'standard case'. This testing, it is hoped, will reveal whether the results are particularly sensitive to the choice of parameter values.

This technique, while simple and readily explicable, suffers from several weaknesses. The analyst has to select the parameters to vary, there is often no *a priori* basis for the choice of variation in a parameter, only point estimates are employed for any parameter, and parameters are usually varied independently. These perceived weaknesses have led to more sophisticated methodologies for coping with risk. Forbes (1983) reports how risk can be handled more systematically by employing subjective probability distributions for parameter values and allowing parameters to vary simultaneously. The analytical method for risk evaluation requires analysts first to determine the key stochastic variables for the project and then to obtain subjective probability estimates for the chosen parameters. These probability distributions can be employed in a numerical simulation to generate probability distributions of outcomes when the parameters are allowed to vary simultaneously. While sophistication is achieved at the price of computer time required to conduct the simulation, the payoff is an enhanced understanding of the expected values and measures of dispersion such as variance of the net benefits of the project.

This methodology is valuable where there is uncertainty about parameter values required as components for a cost benefit analysis. However, there remains the problem of uncertainty facing people directly affected by the programme or policy proposal. This type of uncertainty has an impact directly on individuals' welfare. Capture of those welfare effects is by way of option value or option price and these can be estimated via the techniques described below.

CHAPTER 4

Total value

In the 1980s progress was made toward establishing a coherent basis for valuation. This chapter presents an overview of the total value framework, identifying option value as part of the total value attached to environmental assets. Value has many meanings. This publication is concerned with values that arise from a preference (U) relationship between an individual and an environmental asset (Q). At a fundamental level, each individual is seen to be endowed with *held values* that describe qualities and norms. Held values can differ according to social and cultural groupings. For example, Maori abhorrence of development projects that mix the waters of significant rivers is a held value. Given these held values, the preference relationship between a person and an object results in *assigned values* (Brown, 1984). The assigned value, or relative worth, of an object therefore depends on the particular context and reflects the held values and the perceptive faculties of the individual.

$$\textit{held value} \rightarrow U(Q) \rightarrow \textit{assigned value}$$

The object of individual preferences is a state of the world Q. Figure 4.1 shows a total value curve for the appropriate Hicksian compensation measures of changes in groundwater nitrogen concentrations (ΔQ).

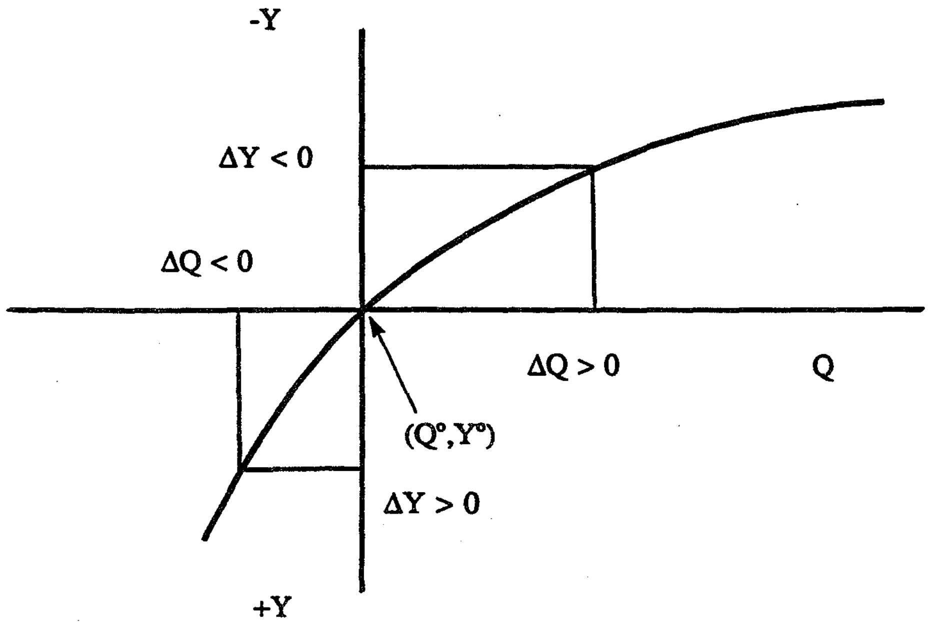

Figure 4.1 **Total value.**

The individual's initial position is given by (Q^o,Y^o), where Q^o is the initial state of the aquifer's water quality and Y^o is initial income (Bradford, 1970; Randall, 1987a). The individual is shown to be willing to forego income \$($\Delta Y<0$) to obtain a higher quality environment for $\Delta Q>0$ and is willing to accept additional income (compensation) \$($\Delta Y>0$) for a lower quality environment $\Delta Q<0$. The total value curve is therefore expressed in terms of income adjustments (ΔY) for changes in nitrogen concentrations (ΔQ) relative to the individual's initial welfare position.

The total value of an environmental asset is derived as follows (Randall, 1987b). The consumer is assumed to produce activities - including, for example, income-generation, recreation and education - using an approach (akin to a firm's production function) that is unique to the individual (Lancaster, 1966). Formally, the individual's optimisation problem is to minimise expenditures on purchased goods so as to achieve a given level of utility.

$$\begin{aligned} &\min_{\{X\}} PX \\ &\text{s.t. } U(Z) \geq U(Z^o) \\ &Z = g(X,Q) \end{aligned} \tag{3}$$

where

P = vector of prices
Z = household activities
Q = environmental services
X = other goods and services
g = household production function

Solving (3) yields an expenditure function $E^o(P,Q,U^o)$. The derivative of the expenditure function that is obtained from (3) yields the inverse compensated demand function for Q (Varian, 1978).

$$\partial E^o/\partial Q = -E^o_q(P,Q,U^o) \tag{4}$$

The total value of Q^o to individual i at t is:

$$V_i(t) = -\int_0^{Q^o} E_q^o(P,Q,U^o)dQ \tag{5}$$

The value of Q^o to n individuals at t is:

$$V(t) = \sum_{i=1}^{n} V_i(t) \tag{6}$$

If:

$$Q(t) = \text{flow of environmental services, } t \in [o, \infty]$$
$$r = \text{discount rate}$$

then the present value of the environmental asset Q is:

$$P_o = \int_o^\infty V(t)e^{-rt}dt \qquad (7)$$

Several difficulties arise from the derivation of the present value of Q.

1. The value person i attaches to Q is complicated by temporal linkages. Assume for the moment that the individual's production function (g) does not change. The value $V_i(t)$ must be defined over the natural life of the individual. For example, the individual could, on the basis of existing information and expectations about future supply and demand, attach a low current value $V_i(0)$ and a relatively high value in 20 years time $V_i(20)$. Although $V_i(t)$ is derived from the individual's decision-making problem characterised in (3) it can be influenced by factors exogenous to the person's decision-making framework. Factors such as information about the outcome of scientific research on environmental assets and natural catastrophes can alter $V_i(t)$. It is conceivable that this information reaches the individual who then adjusts expectations and, therefore, future values. In other words, $V_i(0)$ is linked to $V_i(20)$ in a way that can be influenced by the arrival of new information regardless of whether the individual actively searches for the information.

2. Specification of the utility function and the activities associated with utility (and therefore value) described in (3) are quite general. Therefore, person i might visit a rain forest (use value), enjoy watching a video on rain forests (non-use value) or reading about rain forests (non-use value). The total value attached to the rain forest is therefore a composite of these and other values. A range of techniques can provide empirical estimates of the value(s) attached to the rain forest (see, e.g. Kerr and Sharp, 1986). When selecting the valuation technique, attention must be given to the commensurability of the estimates and the compensation test used in cost benefit analysis (Bishop, 1987; Smith, 1987).

3. The production function (g) represents the individual's approach to information processing and the skill with which purchased inputs (X) are combined with the environmental asset (Q) to produce utility. Clearly, g will not be a static mapping rule. For example, individuals can learn from previous experience - perhaps discovering a more challenging and exciting route through a wilderness area. It would seem likely that a gradient of skills would exist across the community at any one time. Over time, information about the relative

merits of different approaches will filter through the community producing new and different production functions.

The significance of utility in understanding intertemporal choice was noted by Jevons (1905). He identified three distinct origins of utility:

> "1. By memory of past events,
> 2. By sensation of present events,
> 3. By anticipation of future events" (p.3).

In recognising Jevons' original insights Loewenstein (1987) incorporated anticipated consumption as a source of utility into a model of intertemporal choice that can be used to examine the impact of anticipation on behaviour. His results cast doubt on the general assumption that the discount rate is independent of the goods for which it is calculated. He found evidence to support a conclusion that some goods have characteristics that have "myopia inducing qualities" - that is, a particular attribute of the good itself produces relatively steep discounting.

In theory, the total (assigned) value attached to an environmental asset is based on held values, or beliefs, and is the product of the way in which individuals combine inputs and process information in everyday decision making. A great deal of research is needed to improve understanding at the level of preference formation, the intertemporal linkages between values and the influence of information in the valuation process. Theory has progressed to a stage where it is possible to identify use value and existence value as two logically distinct concepts of total value. Each component of total value is discussed below.

4.1 Use value

Use value arises from an activity (Z) which is produced by combining purchased goods (X) with the environmental asset (Q). Indirect valuation methods, such as the travel cost method, rely on weak complementarity between an element of X (e.g. travel) and Q (e.g. national park) for estimating use benefits (Maler, 1974; Freeman, 1979). Methods relying on weak complementarity will produce estimates of value that are a subset of use values. The taxonomy described below distinguishes among use values on the basis of: timing of use, uncertainty over future use, and irreversibility (Randall, 1987b).

Past and current use value: here the individual has made decisions regarding use and observations of activities (Z) which allows the application of valuation methods (e.g. travel cost method, hedonic pricing method) based on the assumption of weak complementarity. Use value is *ex post* and confined to Equation (5).

Expected value of future use: in this case, at the time of valuation the individual has yet to purchase inputs X to combine with the services of the environmental asset Q. The individual may, of course, have used Q in the past. However, future use is uncertain and subject to change as new information becomes available. The expected value of future use, or expected consumer surplus (ECS), can be obtained in two ways.

(a) the expected value of future use can be based on projections of past and current use values by assuming that the estimate of value given by equation (6) applies to a (unknown) future population of users (n). For example, use values obtained from using the travel cost method (TCM) could be used to estimate the expected value of future use. Clearly, the underlying production relationship linking X and Q, the supply of information and the individual's experience are relevant here. The greater the time-gap between observed use data and projected use, the more scope there is for fundamental changes to occur in the population of users. It should also be noted that an estimate of expected value of future use, based on past and current use, is an *ex post* valuation.

(b) an alternative to projecting observed use into the future is to survey the population of users for their use intentions. The contingent valuation method (CVM) provides *ex ante* estimates of expected use values.

As a cautionary note, the method used to estimate future use value must be consistent with the welfare-theoretic framework of cost benefit analysis (Smith, 1987). The TCM is an *ex post* valuation method and projections of future use are necessarily anchored in the *ex post* compensation test. On the other hand, the CVM adopts an *ex ante* valuation perspective which is relevant to the *ex ante* compensation test. Therefore, benefit estimates obtained from the TCM and CVM are based on different theoretical constructs. Adding an estimate of use value obtained from applying of the TCM to an estimate of another component of use value obtained by using the CVM is inconsistent with the welfare-theoretic basis of cost-benefit analysis.

Option value: Option price (OP) is an individual's maximum WTP to maintain an option for future use, or the minimum compensation (WTA) required to give up an option for future use. For uncertain users, OP includes the expected value of future use (ECS) plus option value. Option value (OV) is an adjustment, that is either positive or negative, reflecting uncertainty (Bishop, 1987). Equation 8 summarises the relationship.

$$OP = OV + ECS \tag{8}$$

In the absence of an operating contingent market in environmental assets, option price is not observable and must be estimated using the CVM.

From an individual's perspective at t_0, the existing set of activities Z^o describe one state of the world, where a vector of purchased goods and services X^o are combined with the environmental asset in its current state Q^o. Looking toward the future from t_0, there are two broad classes of risk.

(a) Demand risk refers to situations where the variables of demand - *inter alia* the price of other goods, preferences and income - are uncertain. It is possible that a "purchased" option would turn out to be worthless because demand did not eventuate.

(b) Supply risk on the other hand refers to situations where future availability is not guaranteed unless the option is "purchased", but the supply may occur anyway. Of course, a "purchased" option may not be sufficient to guarantee future supply. Natural systems can fail - species become extinct - even though resources have been allocated to their preservation.

Quasi-option value: Quasi-option value is a different concept associated with maintaining future options and is not discussed in detail in this publication. Developed by Arrow and Fisher (1974) and Henry (1974), quasi-option value is the value of emerging information in a situation characterised by irreversibility. Using the example of an aquifer, assume that contamination is irreversible and that:

$$\begin{aligned} t_1,t_2 &= \text{two periods} \\ \alpha &= 0 \Rightarrow \text{aquifer is not contaminated} \\ &= 1 \Rightarrow \text{aquifer is contaminated} \end{aligned}$$

Then, strategy:

A ≡ avoidance $S(\alpha=0,t_1)$ allows **either** $S(\alpha=0,t_2)$ **or** $S(\alpha=1,t_2)$

and

B ≡ contamination $S(\alpha=1,t_1)$ allows **only** $S(\alpha=1,t_2)$

Strategy A, involving a policy aimed at avoiding contamination, keeps future options open whereas Strategy B, perhaps a policy of laissez faire, reduces future options. If contamination is irreversible and new information about the value of avoidance is likely to emerge after Period 1, but before the Period 2 decision must be made, then quasi-option value is positive.

4.2 Existence value

The conceptual basis of existence value is subtle. Simply put, existence value is generated by knowing that the environmental asset exists. It is not a use value, although users - present and future - can attach existence values to the environmental asset. Existence values are not necessarily confined to unique environmental assets threatened with destruction. The original Treaty signed at Waitangi has existence value to many New Zealanders. Some New Zealanders will have benefited from seeing the original document (use value), they may, in addition, attach a value to its continued preservation (existence value).

At the individual level of analysis there is no convincing separation of existence value from use value. In terms of the above model (3) existence values are generated according to:

$$Z = g(X,Q) \tag{9}$$

This description of existence value permits elements of X to combine with Q in the current time period. For example, recent trends in using endangered species in television advertising promoting "environmentally friendly" products could influence viewer appreciation of these species. Even if this information arrives randomly, and unsolicited, the individual's utility is nevertheless the result of a combination of purchased inputs (e.g. X = TV, power, etc.) and an environmental asset (e.g. Q = endangered species). The process by which existence values are formed is not well formulated in contemporary economic models. For example, Equation (9) could be defined to include a variable describing the stock of human capital representing knowledge of the environmental asset Q. The process by which the individual acquires this knowledge must necessarily include elements of X. If this was admitted into the activity production function (g) then the concept of a stock of knowledge about the asset could be modelled. The arrival of new knowledge could be treated as a flow variable augmenting the stock. Further research is needed in this area.

Randall (1987b) describes two subsets of existence value:

Bequest value: bequest value derives from altruism and is the value attached to the knowledge that Q will be available for future generations.

Intrinsic value: intrinsic value is the value attached to Q itself.

CHAPTER 5

Option value

Using the above taxonomy, option value is a use value. Returning to Equation (3), environmental services Q are combined with purchased goods X to produce activities Z that yield utility and hence value. Uncertainty in demand and supply, and the prospect of irreversibility, provide the basis for option value and quasi-option value respectively. This publication is only concerned with option value.

To illustrate option value, consider the community drawing water from an aquifer threatened by the prospect of nitrate contamination. It is possible to avoid contamination by implementing a policy (e.g. land use controls) aimed at curtailing nitrogen use in the region. Because the policy will incur costs (e.g. planning costs, lost production opportunities) the problem is: what is the public's total willingness to pay to prevent uncertain contamination. The situation is characterised by demand and supply uncertainty and option price is the appropriate measure of economic value. More detailed discussion of demand and supply uncertainty is left for Chapter 6. In this chapter we use the model developed by Graham (1981) to illustrate the relevant concepts of (individual) value under conditions of uncertainty.

Let:

Q = proposed policy
i = state of nature, i = a (no nitrate contamination), i = n (nitrate contamination)
π_i = probability of state i
Y_i = income in state i
C_i = contingent claim in state i
δ = 1 if the policy is implemented
= 0 if the policy is not implemented
S_i = surplus (compensating variation) in each state i

Using the von Neuman-Morgenstern theorem, the individual's utility function is expressed as:

$$U = \pi_a U_a(C_a,\delta) + \pi_n U_n(C_n,\delta)$$

The standard assumptions of non-satiation and risk aversion apply throughout. The surplus from policy implementation in each state i is defined as the difference in income with (δ=1) and without (δ=0) the policy on nitrogen control, that is:

$$U_i(Y_i - S_i, \delta=1) = U_i(Y_i, \delta=0) \qquad i=a,n \tag{10}$$

The expected value of the surplus from policy implementation (ECS in Equation (8)) is the sum of the surplus in each state weighted by the probability of that state occurring:

$$E(S) = \pi_a S_a + \pi_n S_n \tag{11}$$

Option price is the *ex ante* reduction in income necessary to make the individual indifferent about the situation where the policy exists ($\delta=1$) and the alternative state where the policy does not exist ($\delta=0$) for given probabilities of contamination (π_i). In other words, option price satisfies the following condition:

$$[\pi_a U_a(Y_a\text{-}OP, \delta=1) + \pi_n U_n(Y_n\text{-}OP, \delta=1)] - [\pi_a U_a(Y_a, \delta=0) + \pi_n U_n(Y_n, \delta=0)] = 0 \tag{12}$$

Equation (12) shows option price as an *ex ante* value which represents a state-independent payment that a consumer would be willing to make to obtain the results of the policy. Payments could, however, be state-dependent and therefore unequal. Equation (13) describes a more general, and analytically convenient, process by which "income" is removed from the individual, in each state, so utility with the policy ($\delta=1$) equals utility without the policy ($\delta=0$). The WTP locus is the set of (γ_a, γ_n) satisfying:

$$[\pi_a U_a(Y_a\text{-}\gamma_a, \delta=1) + \pi_n U_n(Y_n\text{-}\gamma_n, \delta=1)] - [\pi_a U_a(Y_a, \delta=0) + \pi_n U_n(Y_n, \delta=0)] \tag{13}$$

Each pair (γ_a, γ_n) is a measure of WTP based on the "with-without" principle used in cost benefit analysis.

Figure 5.1 shows one possible WTP locus. Recall that option price is the maximum payment the individual is willing to pay in both states. Option price is **independent** of the state that eventuates. Figure 5.1 shows option value to be positive, that is:

$$OV = ECS - OP > 0$$

However, Figure 5.2 shows how a change in the WTP locus, given the state probabilities $\{\pi_a, \pi_n\}$, can result in option value being negative, that is:

$$OV = ECS - OP < 0$$

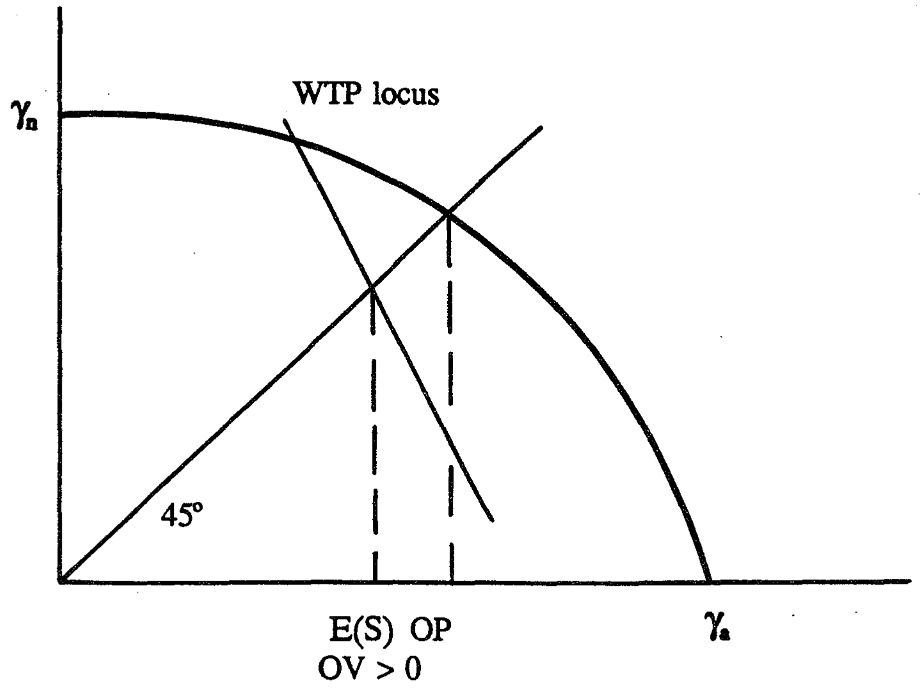

Figure 5.1 Positive option value.

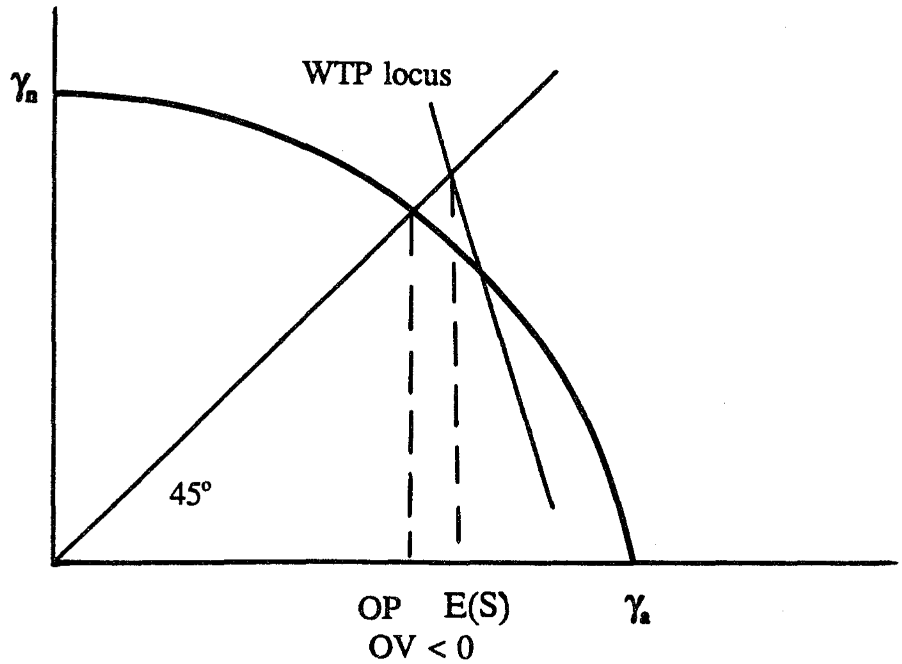

Figure 5.2 Negative option value.

Many economists agree that measurement of ECS is an inadequate estimate of welfare change and recognise that option value is the adjustment to ECS under conditions of uncertainty. The possibility of option value having an ambiguous sign has stimulated a great deal of research aimed at resolving the ambiguity. We now present a summary of the progress made toward resolving this issue.

CHAPTER 6

Sources of uncertainty

In Chapter 3 we described the uncertainty of a future state of the environment (Q), given a certain policy action Z, using a probability distribution $\pi(Q,Z,t)$. The task of the cost benefit analyst is to estimate demand (WTP) and supply (marginal cost) functions in order to identify potential improvements in the efficient allocation of resources. Weisbrod's seminal paper on option value raised doubts about using use benefits to estimate the total benefits of maintaining an environmental asset. If option value is positive then estimating user benefits (i.e. an estimate of expected consumer surplus) would be an underestimate of total benefits. But if option value is negative then user benefits would overstate total benefits. We have shown, using Graham's WTP locus, that the sign of option value can be either negative or positive. This result calls for a more detailed look at the sources of uncertainty to see if theory can establish *a priori* the sign of option value.

Uncertainty can arise either because individual consumers are uncertain about their demand for the environmental asset and/or because of the uncertainty surrounding supply. We now examine the variables underpinning demand and supply to see whether better resolution can be obtained on the sign of option value. In situations where the sign of option value is indeterminate we describe key variables that give rise to this indeterminacy. What emerges out of this chapter is that analysts must carefully characterise the sources of supply and demand uncertainty pertinent to the problem at hand. A good description of the sources of uncertainty will facilitate formulation of better empirical models and allow comparison of *a priori* determinations of the sign of option value with empirical results. We proceed by examining each source of uncertainty in turn before considering the complex situation where both demand and supply uncertainty exists.

6.1 Demand uncertainty

Option price is the maximum amount an individual is WTP now (t_o) for an option to consume Q in the future (t_{o+h}). The option, for example, might be a permit allowing a number of visits to a wilderness area or a right to withdraw water from an aquifer. While ECS may vary across states of the world, option price is constant across these states (i.e. option price is a **state-independent** measure of WTP). Graham's (1981) model does not explicitly consider uncertain variables of demand such as state-dependent income, preferences and the price of other goods (Freeman, 1985). To examine demand-side option value (DSOV) we assume supply certainty and only consider:

$$OP = ECS + DSOV$$

Bishop (1982) shows that it is how the consumer views risks that determines the sign of DSOV. In particular, given relative probabilities $\{\pi_w, \pi_{wo}\}$, prices and conditional incomes, Bishop shows that the sign of DSOV depends on the relationship among the conditional marginal utilities of income. Plummer and Hartman (1986) present a more general model of the problem where the state of the world is determined by a state variable (T) which can be used to represent income and tastes. They evaluate a proposed change in the price of a good (Q), $P_o \rightarrow P_1$ where $P_1 < P_o$, say at t_{o+h}. Their results support Bishop's conclusion, showing that the sign of DSOV is the same as the sign of the correlation between ECS and the marginal utilities of income (U_M) across states of the world. Plummer and Hartman analyse uncertainty using the following relationship derived in the form of a theorem:

$$\text{sign OV} = \text{sign}(dECS/dT)\text{sign}(dU_M/dT)$$

Income

The price reduction ($P_o \rightarrow P_1$) is assumed to occur at a time when income is uncertain. For a risk-averse person facing income uncertainty, the sign is determinate DSOV<0. Therefore, ECS overstates state-independent WTP (option price).

Tastes

As Plummer and Hartman note, tastes are generally unobservable and there are few grounds, in theory, for restricting taste-related changes in behaviour in other than arbitrary ways. They show that DSOV, for the same individual, can be positive or negative depending on the probability distribution rather than the changes in ECS or U_M across states. In general it is not possible to determine *a priori* the sign of DSOV when uncertain preferences are involved.

6.2 Supply uncertainty

The possibility of supply-side uncertainty, although first raised by Cicchetti and Freeman (1971), was first modelled by Bishop (1982). Assuming demand certainty and a two-state world, Bishop showed that supply-side option value (SSOV) is unambiguously positive. Using a more general framework, Freeman (1985) structured his analysis around four possible cases of supply-side uncertainty. A hypothetical project is assumed to supply a public good. Without the project, the probability of supply is π_{wo}; with the project the probability of supply is π_w, where $\pi_w > \pi_{wo}$. On the side of demand, individuals are assumed to be risk averse and there is no uncertainty in the determinants of demand. Option price is the payment for the project that equates expected utility with and without the project. The sign of SSOV is shown for each of the four cases. Eliminating demand-side uncertainty, we can examine the following relationship:

$$OP = ECS + SSOV$$

Case A: $\pi_w=1$, $\pi_{wo}=0$. SSOV = 0
There is no uncertainty associated with either state and, therefore, option price equals ECS.

Case B: $\pi_w=1$, $0<\pi_{wo}<1$. SSOV > 0
Without the project the individual holds a lottery ticket (i.e. an uncertain right to consume a public good that might be available). The risk-averse person will pay more than ECS to eliminate the uncertainty of supply, and option value in this case is the risk premium that the person is willing to pay.

Case C: $\pi_w<1$, $\pi_{wo}=0$. SSOV is *a priori* indeterminate
If the individual's WTP for the public good is independent of income, then OP<ECS and SSOV<0. Using Cook and Graham's (1977) measure of consumer surplus as a function of income, Freeman (1985) shows that if the income elasticity of demand for the environmental good is positive then ECS with the project must be adjusted for the income effect to give (ECS^*) where $ECS>ECS^*$. It is now possible for option price to exceed ECS and therefore SSOV>0. The two variables important in reaching this result are first the adjustment to ECS to account for the income effect of the project, and second the probability attached to the supply of the good (π_w).

Case D: $0<\pi_{wo}<\pi_w<1$. SSOV is *a priori* indeterminate
If the individual's WTP for the public good is independent of income, then OP<ECS and SSOV<0. However, if the income elasticity of demand is positive then option price can exceed the net addition (π_w-π_{wo}) to ECS and SSOV>0. In this case, the sign of SSOV depends on the relative magnitudes of the probability of supply and the income effect.

Freeman's (1985) paper led Plummer (1986) to suggest a more general framework for considering option value, where option price is defined as:

$$OP = OP(\pi_w,\pi_{wo},Y,G)$$

where:

π_w = probability of supply with the project
π_{wo} = probability of supply without the project
Y = income
G = public good

then option value is given by:

$$OV = OP - (\pi_{wo}-\pi_w)ECS$$

Plummer's results support Freeman's (1985) conclusions on the sign of option value. His formulation highlights the significance of the relationship between the relative probabilities and ECS.

6.3 Demand and supply uncertainty

We now consider the implications of considering supply-side uncertainty and demand-side uncertainty together. Returning to our earlier example of ground water pollution for the moment, most policies aimed at controlling nitrogen levels in an aquifer will not eliminate supply-side risk. The set of policy options (including the status quo option) will, most likely, produce a set of probability distributions, each describing the likelihood of a particular state (Q_s = 15 ppm) occurring. Therefore, estimating consumer WTP necessarily includes the value of a hedge against demand-side uncertainty given supply-side uncertainty (Freeman, 1985).

Determining the sign of option value, when both supply and demand are uncertain, is difficult. Freeman (1985) concludes that the sign is ambiguous and depends on:

- the pattern of supply uncertainty reflected in $\{\pi_w, \pi_{wo}\}$

- the determinants of demand uncertainty

- the degree of demand uncertainty.

Theoretical research has, to date, been unable to provide unambiguous results. Moreover, it appears that it is unlikely that general statements can be made *a priori* about the sign of option value (Freeman, 1985; Plummer, 1986). This leaves the sign to be determined through empirical analysis based on specific probability distributions and utility functions that represent consumer preferences. This conclusion foreshadows the cautions we raise later for those undertaking empirical research.

CHAPTER 7

Measurement of option price and option value

The relationship between option price and option value is well captured by Smith's (1987) definition:

> "Option value is the difference between the option price and the expected value of the consumer surpluses under each state of nature. It compares what might be termed an *ex ante* welfare concept (i.e. the option price) with an *ex post* concept (the expected value of the consumer surplus derived for the policy when each state is treated as certain)" (p.289).

Before commencing attempts to measure option value, researchers should consider whether there is a genuine need for measurement. In many, perhaps all, circumstances measurement of option price is likely to be a superior strategy. The reasons for this conclusion are quite straightforward. To paraphrase Smith (1987, p.289), option value is not a distinct component of value and has limited relevance. It is of value because it is useful for judging the magnitude of the error if one chooses to use expected consumer surplus as a proxy for option price.

Given this advice and the feasibility of measuring option price, researchers should consider carefully whether there is a need or good reason to measure option value. Circumstances that could necessitate measurement of option value seem to be cases where consumers' surplus, can, or has been measured. An example is travel cost estimates of recreation values for a natural area. In those situations measuring option value will inform analysts of the potential error if consumers' surplus is used. However, if measuring option value is possible, then measuring option price is likely to be equally feasible. If use of one measurement (option price) is preferable to the use of two measures combined (consumers' surplus plus option value), then option price seems the appropriate target to aim for. The conclusion is, unless there are compelling reasons for needing to know the magnitude of option value but not the magnitude of option price, then researchers should strive to measure option price.

If we dismiss the case for measuring option value alone on grounds of limited relevance and preference for one measure over two, this heightens the case for measuring option price. Smith argues evaluation of:

> "Option Price should be a central element in the development of a consistent *ex ante* framework for benefit analyses when a policy changes resources, the conditions of access to them under uncertainty, or the nature of the uncertainty itself" (p.291).

In practice, researchers can often generate data allowing estimation of option price, option value, and consumers' surplus. In this chapter we focus on techniques to generate both option price and option value.

Our concern is with welfare change under uncertainty. A variety of circumstances can lead to uncertainty and this may necessitate research directed at each of these situations. In particular, uncertainty can arise in the demand for a good or service and/or in the supply of a good or service. An example is useful to illustrate these possibilities. Edwards (1988) studied the willingness to pay of residents of Cape Cod, Massachussets, to prevent future contamination of groundwater. Residents faced demand-side uncertainty because they could not be certain whether they would live in the study area in future, and hence did not know whether they would receive any direct benefits from preventative action. Equally the likelihood and timing of contamination of the groundwater supplies in the absence of intervention was unknown, and residents were unsure as to whether intervention would supply any useful service and when that useful service would occur.

While it may appear relatively simple to survey individuals and obtain their statements about the effect on their welfare of some policy proposal, in practice obtaining useful and accurate estimates of non-use values, option prices and option values requires considerable subtlety. Much research effort has been directed at developing and improving measurement techniques. However, understanding the concepts must precede any attempts to estimate the magnitudes of option values and option prices. Measuring value is founded on an underlying theoretical structure and this structure must be considered when designing any empirical study. Smith (1987) comments that many studies have mixed *ex ante* and *ex post* perspectives, asked questions that are not consistent with the theoretical structure they use to interpret the results, asked questions that are too vague and hence conflate several types of values. There is a danger too that individuals will foresee an opportunity to free ride and hence will understate their true evaluations of the utility gain associated with reduction in uncertainty.

While preceding chapters have explored the theoretical basis of the concepts, a real world example can illustrate some of the pitfalls associated with too-casual use of the idea of option value. A recent report (Stone, 1991) revealed that a New Zealand government department stores 700 000 maps in a Lower Hut warehouse. Storage of course implies costs - in this case a reported cost of $4.3 million - and prompts the question of whether these costs are justified by the benefits that off-set them. Both use and non-use benefits might be claimed to be achievable because of the storage of the maps. Use benefits will arise when the maps are eventually sold, but non-use benefits might also be claimed to occur, including option and existence values.

Some care is required in partitioning benefits into the various components, and use of the words *option* and *existence value* is not sufficient to ensure that option and existence value are being evaluated. An argument that storing the maps allows the option to call upon the maps in the event of some emergency - flood, earthquake, search - points to some future *use* of the maps. Option value, by comparison, could arise if society places a value on uncertainty associated with future supply of the maps. A similar analysis can be applied to assertions about existence value. While it is possible that individuals may derive some utility purely from knowing that the maps exist, this should be sharply distinguished from the utility that arises from knowing that the maps are available for use in the future. The conclusion is that studies aimed at measuring non-use values must ensure that their research tool discriminates between use and non-use values.

Vagueness of study techniques can also lead to error of a second type. If a contingent valuation method study is employed and individuals are asked a 'willingness to pay' question, the question format has to describe: the type of uncertainty, the time period involved, the mechanisms for resolving the uncertainty, and the opportunities that are available to individuals to adjust their behaviour to risk. Failure to identify the precise context in which respondents are to consider the 'willingness to pay' question is almost certain to lead to respondents formulating their own scenario and answering accordingly. Accurate interpretation of their responses will require enlightened second-guessing about each respondent's decision context. In practice this is impossible to achieve and researchers will typically apply their chosen theoretical structure when analysing the results. Clearly this failure to establish in the survey the exact circumstances to be considered by respondents, should evoke considerable caution in interpreting any results generated.

If the map storage example is again considered, surveys to determine option value associated with storing maps should delineate a number of items before respondents are asked 'willingness to pay' questions, including: the likelihood of future supply with and without the Lower Hutt storage, the nature and availability of any map alternatives (e.g. aerial photographs, Landsat images, GIS data, GMS data), the time period in which uncertainty in supply is to be considered, the possibility of using alternative contractual methods of dealing with risk, the constraints on respondents' ability to free ride. Failure to deal with these issues is likely to reduce sharply the value of any responses obtained.

Collecting information to estimate option price involves the same considerations as valuing other non-market goods. As Bohm (1975) observes:

> " ... from a practical viewpoint, estimating option price does not add any new dimensions to the measurement problem that always exists for cases where an estimate of consumer's surplus is required" (p.736).

Two workable techniques exist at present, a direct method (contingent valuation method (CVM)) and an indirect method (hedonic pricing method (HPM)). Of the two, CVM is by far the most widely used.

7.1 Contingent valuation method

The CVM typically requires that researchers ask a survey population questions on their willingness to pay to attain some outcome. Bishop *et al.* (1983) describe the technique as follows:

> "Contingent valuation employs personal and telephone interviews and mail surveys to ask people about the values they would place on non-market commodities if markets did exist or other means of payment such as taxes were in effect. That is subjects are asked about willingness-to-pay or compensation demanded *contingent* on the creation of a market or other means of payment. All payments and receipts are purely hypothetical" (p.619).

The groundwater contamination example can again be used to illustrate the technique. After defining the survey population, a sample of respondents could be asked about their willingness to pay to prevent future groundwater contamination. The survey format can be varied to posit the question in the context of demand-side and supply-side uncertainty. Depending on the nature of the survey questions, the information generated can be employed to calculate expected consumer surplus, option value, option price and existence value. Where the targets are option value and option price, CVM surveys require a format that describes the nature of the problem (e.g. possible groundwater contamination), explains the areas of uncertainty such as the stochastic nature of future contamination, and ensures that meaningful hypothetical contingent contracts are considered by respondents.

Once 'the problem' is correctly and accurately specified, respondents can be asked 'willingness to pay' questions, including questions directed at obtaining insights into how important uncertainty is to respondents. The questions can take the form:

> *"What is the maximum additional amount you would be willing to pay per year on your water bills to prevent future nitrate contamination of groundwater from agricultural runoff in this region?"*

This open-ended question format will elicit bids that can be used to calculate welfare gains associated with preventing possible future groundwater contamination. Other question formats exist including dichotomous choice questions where respondents are asked:

> *"Would you be willing to pay [$Z] per year on your water bill?"*

The amount specified - *[$Z]* - can be varied amongst respondents and the pattern of "yes" and "no" answers can be employed in a logistic or other analysis to calculate expected maximum willingness to pay. This dichotomous choice format is frequently preferred to open-ended formats in non market valuation studies, because it is believed that respondents are more familiar with this type of decision situation and hence can provide more accurate answers to the evaluation questions (Kerr, 1986; Mitchell and Carson, 1989).

Calculating welfare losses due to groundwater contamination is predicated on a simple idea that respondents will be indifferent between the utility reduction that occurs because of the income loss represented by their bids, and the utility loss that will arise if the groundwater contamination occurs. Measuring welfare change requires some judgement about whether individuals act strictly rationally or follow other behaviour patterns. Much work in economics uses expected utility theory to explain behaviour in the face of uncertainty. Expected utility theory is predicated on the idea that individuals are rational decision makers who can calculate the expected values for various options by weighting the value of each outcome by the probability of the outcome occurring. Individuals are typically believed to be risk averse and to derive less utility from an uncertain than from a certain outcome. A simple example illustrates these ideas and the effect of uncertainty on utility.

If an individual is concerned about groundwater quality then contamination of groundwater will reduce the individual's welfare. We can consider a two state world with $U_1(*)$ describing utility realised in the desirable state and $U_2(*)$ the undesirable. The individual's income in the two-state world is given by Y_1 and Y_2, where $Y_1 > Y_2$. The probabilities that these states will occur are π for the desirable state, and $(1-\pi)$ for the undesirable. The rationale employed to appraise welfare loss, typically, is to argue that individuals who face uncertainty will be prepared to pay an option price such that:

$$U_1(Y_1-OP) = \pi U_1(Y_1) + (1-\pi)U_2(Y_2) \qquad (14)$$

Payment of option price by the individual will ensure the desirable outcome occurs, but their utility will be reduced because they have a lower disposable income remaining. Alternatively, if the individual chooses not to make payment of option price and if contamination of the groundwater does occur, the individual will have a reduced income of Y_2 leading to lower utility for that course of action.

While the logic of expected utility theory is persuasive to many economists, research has demonstrated that the behaviour of individuals does not always conform to the predictions of the theory (Kahneman and Tversky, 1982). Despite this difficulty, much research attempting to evaluate welfare loss in the face of uncertainty is based on an expected utility framework.

Researchers often assume that individuals are risk averse, but individuals can be risk lovers, risk neutral or risk averse and the effect of uncertainty on their welfare is therefore *a priori* unpredictable. This should not invalidate the information from studies to elicit option prices and option values as long as respondents are not constrained to provide only certain types of responses. Contingent valuation studies can be tailored to cope with these requirements.

Contingent valuation is a modern technique but in 25 years of use the technique has been steadily refined as theorists and researchers have grappled with both conceptual and practical problems associated with its use. Notably, in the context of option value, researchers have worked to ensure that there is a clear distinction between option price and option value, that the nature of the uncertainty is made clear to respondents, and that respondents are assured free riding is not a possibility. These considerations have not always been recognised in the past and scrutiny of published option price/option value studies reveals many have quite serious shortcomings of the type described in the preceding chapter.

Early attempts to obtain estimates of option value (Greenley *et al.,* 1981; Brookshire *et al.,* 1983; Schulze *et al.,* 1983) failed to specify precisely the nature of the uncertainty confronting respondents, did not satisfactorily explain to respondents how their responses would be linked to future outcomes, asked respondents to consider situations where there would be **certain changes** in resource availability, did not completely rule out free riding, and inadvertently conflated option price and option value. This lengthy list of weaknesses undermines much of the value of these research efforts. Equally, shortcomings of these types may provide an explanation for some of the surprisingly large 'option values' estimated in some studies.

Estimates of option value equal to 50% of the magnitude of user values (Fisher and Raucher, 1984), or 145% of the magnitude of user values (Sutherland and Walsh, 1985), must be interpreted in the light of the comments in the preceding paragraph. Sutherland and Walsh (1985) in a study of possible water quality degradation in Flathead Lake and River, Montana, attempt to establish several values including option and use value. The remarkably large figure they obtain for 'option value' can be understood by considering the CVM question employed to provide data on option value. Respondents were first asked what was the maximum amount their household would be willing to pay annually to protect water quality on the Flathead Lake and River. Subsequently they were asked:

> *"[What percentage of that figure would your household be willing to pay annually] for the opportunity to visit the Lake or River in the future at the same level of water quality and fishing conditions?"*

It seems clear that questions of this form to elicit data on option and other non-use values are problematic for three reasons. First, if researchers are attempting to subdivide the total figure stated into the various non-use categories, there is a problem of lack of independence among the quantities estimated. For example, consider a case where a household has indicated that the maximum amount it is willing to pay to protect water quality is $100 per year, and this amount is to be allocated between four categories of value. Once the household has indicated the proportions of the $100 it attributes to say recreation use value and option value, the remaining two proportions must be determined simultaneously. Second, in practice, respondents are likely to nominate a percentage figure that indicates their willingness to pay for future use and hence the researchers are in fact measuring option price and not option value. Third, the percentage figure stated by respondents will be influenced by their uncertainty in demand for these recreation resources. Demand-side uncertainty is a legitimate area for investigation, but this is quite different from willingness to pay to combat supply-side uncertainty associated with future water quality.

Walsh *et al.* (1984), in a study of wilderness protection in Colorado, report aggregate option value of approximately 16% of total preservation value, and between 17.5 and 33.3% of aggregate use value. The range for 'option value' as a percentage of aggregate use value is also of dubious merit as the survey question asked households about their willingness to pay for:

"the option to visit existing or potential wilderness areas in the future?"

Walsh *et al.* argue that this question was not misinterpreted as a question about option price. The concern, however, is that their question does not confront respondents with the key issue of uncertainty and the form that uncertainty can take. Equally the links between payments made and reductions in uncertainty are not made explicit. The conclusion, here as in other studies directed at evaluating option value, is that great care must be taken in the formulation of the survey instrument if researchers are to succeed in their chosen tasks.

Edwards (1988), in a study of potential groundwater contamination at Cape Cod, Massachussetts, succeeds in isolating the effects of uncertainty in supply on welfare. His CVM study employed 10 different versions of a questionnaire and posited information on:

(a) the year of expected future contamination (5, 10, 20, and 40 years in the future),

(b) the probability of nitrate contamination without a regional aquifer management plan given a five-year time horizon (100, 75, 50 and 25%),

(c) the probability of contamination with a management plan given a five-year time horizon (0 and 25%),

(d) the price of bottled water.

Based on the particular time horizon posited respondents provided information on the likelihood that they would be living in the region at the time of expected contamination thus providing subjective information on demand uncertainty for personal use of the aquifer. The questionnaire versions corresponding to factors (b) and (c) assigned supply uncertainties. Valuation was tackled using dichotomous choice questions about willingness to pay to prevent future contamination.

Edwards reports option value to be approximately one percent of option price for this study. If this result is valid then the benefits of groundwater management can be approximated as the increase in expected value of benefits without having to measure option value or option price (Edwards, 1988, p.486). Given the difficulty in obtaining a high degree of accuracy in CVM studies, a one percent difference between the expected value of benefits and option price seems to be of little practical significance. Of interest also is Edwards' comment that planners and resource managers who work only with certain, worst case scenarios, are likely to overestimate substantially the benefits of averting uncertain, future contamination. The probability of supply of uncontaminated groundwater without management influence exerts a strong influence on option price.

7.2 Hedonic price method

Smith (1985) explains how the hedonic price method could be used to measure option price. A policy change may increase the probability of some favourable outcome occurring. If p represents the original probability of an event occurring, and g represents the increased probability of the favourable outcome occurring subject to payment of option price, then:

$$(p+g)U_1(Y_1\text{-}OP) + (1\text{-}p\text{-}g)U_2(Y_2\text{-}OP) = pU_1(Y_1) + (1\text{-}p)U_2(Y_2) \qquad (15)$$

If g can vary and we can observe the changes in OP required to maintain a constant expected level of utility then the option price-risk schedule will be given by:

$$\partial OP/\partial g = [U_1(Y_1)\text{-}U_2(Y_2)]/[(p+g)\partial U_1/\partial Y_1 + (1\text{-}p\text{-}g)\partial U_2/\partial Y_2] \qquad (16)$$

A point estimate of the option price-risk relationship can be calculated from hedonic price models where price is influenced by risk of some kind. Hedonic price models of housing markets and labour markets have been employed to determine the role of risk in influencing house prices (Brookshire *et al.*, 1985) and wage rates (Harrison and Stock, 1984). While these studies point to a potentially useable means of estimating option value there are some difficulties in interpreting incremental option price estimates. Analysts must understand how respondents perceive and respond to the risk changes that are believed to be valued in the study. A further requirement is the need to have other than a dichotomous variable influencing the dependent variable studied, if researchers wish to make comments about the option price-risk gradient.

Brookshire *et al.* (1985) consider cases where houses in Los Angeles counties and San Francisco Bay counties are located either in Special Studies Zones (SSZs) - designated areas of elevated relative risk determined by potentially and recently active earthquake fault traces - or are in locations of average risk. Their study involved asking if people living in households in the two areas would pay a premium in the form of higher housing values for homes located outside an SSZ and the magnitude of their willingness to pay. The property value differential can be expected to provide an estimate of the option price for the reduction in perceived risk (Smith, 1987). The dichotomous nature of the choice confronting individuals does increase the difficulty of interpretation when researchers wish to infer the option price-risk gradient. However, in other situations where there is a 'gradation' of hazard with 'location' a schedule of risk against price change can be constructed.

Generation of data via hedonic price method studies depends on a number of conditions being met including the availability and perception by individuals of information on the 'hazard', the ability of individuals to respond to that information in the relevant markets, and the efficiency of those markets (Kerr, 1986). In practice, those are quite demanding requirements but, those caveats aside, the hedonic price method does provide a feasible means of estimating option price.

CHAPTER 8

Bounds for option value

Considerable ink has been spilled over the topic of option value as economists have struggled to pin down the nature of the concept and determine its importance. We summarised the findings of theoretical research on option value in Chapter 6. Empirical testing to determine the magnitude and importance of option value has produced widely varying results. An alternative approach is to attempt to provide analytical bounds for option value followed by use of a cardinal utility model and numerical calculations. Freeman (1984) attempts first to determine *a priori* the sign of option value and then to establish whether option value is likely to be large enough to make any difference in a cost-benefit analysis. Smith (1984) attempts to establish an analytical bound for option value and focuses in particular on the uniqueness of the good or service in question.

Freeman employs a standard utility model to explore the relationship between option price and expected value of consumer surplus, and hence the sign of option value in various situations including income uncertainty, price uncertainty, and state-dependent preferences. His principal conclusion from the theoretical analysis is:

> " ... that for risk averse individuals, option value is positive for a plausible model of that case of most interest in the environmental economics literature - where demand uncertainty arises from some exogenous factor (other than price or income) which does not affect the marginal utility of income and attitudes towards risk across states" (p.11).

Theoretical analysis completed, he turns to numerical calculations to determine how big option value might be? His numerical simulations examine a considerable number of scenarios including: three income levels, four utility functions reflecting differing levels of risk aversion, four probabilities of the undesirable outcome occurring, and three levels of consumer surplus as a proportion of income. His conclusions are quite clear. For the case of state-dependent preferences, option value as a percentage of expected value of consumer surplus substantially exceeds 10% only in those cases where the degree of risk aversion is high, the probability of demand for the good or service is low, and consumer surplus as a proportion of income is high (Freeman, 1984, p.9). Where demand uncertainty arises from uncertainty about future income, option value is often negative for risk-averse individuals and use of expected value of consumer surplus in a cost-benefit analysis would give an overestimate of option price. Freeman notes that:

"In many apparently plausible cases, negative option values are quite large relative to expected consumer surplus. In those cases reliance on estimates of expected consumer surplus could lead to substantial overestimates of option prices and benefits" (p.11).

Freeman further notes that his results cast considerable doubt on the validity of the results from empirical estimates of option value reported in earlier studies. Greenley *et al.* (1981), for example, report that option value for recreation in the South Platte River was $23 per household per year. Freeman employs a cardinal utility function to calculate that option value could be no more than 7.4c (Freeman, 1984, p.12). In the light of this severe divergence in results he concludes that:

" ... it appears crucially important that as a first step the nature and source of the demand uncertainty be identified. Then well-specified models of individual choice can be developed and used as the basis of testing with whatever data are being used. Then we will be able to consider whether the data are consistent with our models of option value - or whether the models must be rejected as inconsistent with the empirical evidence" (p.12).

The empirical evidence from a later, carefully conducted empirical study (Edwards, 1988), appears to support Freeman's conclusion that for cases of state-dependent preferences, option value is small relative to expected consumers' surplus.

Smith (1984) relies upon a theoretical model to generalise the results of Freeman (1984). By employing an index of uniqueness and a state-dependent utility model, Smith reaches some simple conclusions about the bounds on option value as a fraction of ECS for a two-state world.

" ... the degree of demand uncertainty and the uniqueness of the good are the key ingredients in determining the magnitude of option value in comparison to the expected user value" (p.294).

The ratio of option value to ECS varies inversely with the probability of desiring access to the good or service in question, and varies directly with the degree of uniqueness of the good or service. Smith concludes that:

" ... the relationship between option value and expected consumer surplus will vary with the nature of the environmental resource under scrutiny. ... Equally importantly it seems reasonable to expect that there will be differences in the intensity of preferences for these goods and services across individuals. Empirical research that seeks to develop operational rules for estimated ratios of option value to expected user values will need to consider both of these factors if the resulting suggestions for future benefit estimation are to provide plausible approximations for this component of intrinsic values" (pp.294-295).

Bishop (1988) reviews the various attempts to determine the sign of option value and reaches a gloomy conclusion about the outcomes and the chances of further progress on this front.

> "Theoretical analysis on the demand and supply sides have convincingly shown that **a priori** attempts to determine the sign are unsuccessful except in special situations like the Bishop case or where specific information about the utility functions is available" (p.91).

Bishop observes that the sign of option value is important and option value cannot be ignored in cost-benefit analysis. Given the existence of the brick wall that blocks theoretical determination of the sign of option value, Bishop recommends laboratory and field experiments to investigate further the role of uncertainty in influencing welfare. Controlled experiments using real money:

> " ... could help establish the validity of contingent option price, option value, and consumer surplus estimates" (p.92).

The messages to be drawn from the work of Freeman and Smith are that if we are prepared to make some assumptions about the nature of the utility function and marginal utilities in various states of the world, we can gain some *a priori* insights into the likely importance and size of option value relative to ECS. In circumstances where the good or service is not readily replaced (i.e. has few substitutes) and individuals are risk averse, option value can be a significant positive amount. In circumstances where there is considerable demand uncertainty, perhaps because of uncertainty about future incomes and prices, option value can be a significant negative amount.

In New Zealand, cost-benefit analyses of projects that have an impact on important features - national parks, endangered species, historic sites, urupa (Maori burial sites) - should attempt to include option value or option price estimates in their evaluations. Cost-benefit analyses of situations where the goods or services in question have high income elasticities of demand or where goods and services are subject to fluctuations in demand, are likely to be situations where there is demand uncertainty and where option value is likely to be significant and negative.

CHAPTER 9

Including option value in cost-benefit analysis

Assume a researcher is faced with the task of completing a cost-benefit analysis of a proposal to prevent groundwater contamination. The potential Pareto improvement test requires that total willingness to pay for the project exceeds the costs of the project. The researcher will typically first attempt to identify all of the costs and benefits associated with the proposal, then subsequently will attempt to estimate magnitudes for these costs and benefits. These listings and evaluations of benefits and costs should attempt to encompass all welfare effects associated with the project. In the case of the groundwater contamination control programme, the proposal will bring uncertain benefits to people who rely upon or may in future rely upon the groundwater. The programme may also provide benefits to people in the form of existence or bequest values. Where there is uncertainty, this is likely to affect individuals' welfare, and this effect, if possible, should be included in the cost-benefit analysis of the project.

Measuring welfare effects requires that an appropriate welfare measure is selected, prior to selecting of the measurement technique. Earlier chapters of this publication indicated that the expected value of consumer surplus and option price are two possible measures of a change in welfare. Option price is widely preferred to consumer surplus on grounds of accuracy. In the situation proposed above, the appropriate action is to obtain estimates of option price associated with controlling groundwater contamination. Option price estimates will provide *ex ante* information on individuals' willingness to pay for the benefits associated with controlling groundwater contamination. Contingent valuation is the obvious technique to employ when estimating option price. As well, if there are existence or bequest values, they could be measured by a contingent valuation technique and included in the estimation of total benefits. It is important to stress that the willingness to pay, contingent valuation questions, must be preceded by carefully thought out information on the date of expected future contamination, the probability of contamination with and without management intervention, and the prices of substitute goods. Edwards (1988) provides an excellent model of the appropriate way to provide relevant information for survey respondents, and the nature of the willingness to pay questions.

Option price measures have not previously been widely used in cost-benefit analyses as researchers have typically relied upon ECS measures. This widespread use of ECS measures has occurred because of their apparent ease of measurement compared to other measures. In the USA, acceptance by the courts of the superiority of consumer surplus as a measure of welfare gains and losses over impact effects such as change in sales or employment has been noted as a major gain

(McConnell, 1991). However, option price provides an even better estimate of the welfare effects of projects subject to uncertainty, and should be the measure of choice where it can be estimated.

In some cost-benefit analysis situations researchers may choose to use a technique such as the travel cost method to estimate ECS. Consumer surplus is often an incomplete and hence inappropriate measure of welfare gain or loss and the researcher may wish to include welfare estimates for option value, existence value and bequest value. A standard travel cost model does not generate data that can be used to estimate these influences on welfare and another technique is required. Contingent valuation is the obvious alternative technique and can be used to generate estimates for these values. The estimates for option value, so calculated, can be used to determine how useful the consumer surplus estimate is. But obvious alternative strategies exist including: use the CVM and estimate option price initially instead of estimating consumers' surplus; or, use the CVM and estimate option price instead of estimating option value and adding this to consumers' surplus. It is important to remember that option value is not a distinct component of value and is only of interest as an indicator of the error perpetrated by using consumer surplus as a welfare measure. Except for circumstances that explicitly require estimation of option value, focusing on option price appears to be the least problematic approach when researchers have to consider the effects of uncertainty on welfare.

9.1 Reliability of contingent valuation

Contingent valuation studies require careful data collection. Several data collection techniques are available including bidding games, contingent ranking, open-ended question and dichotomous choice formats. Researchers have to consider the possibility that their survey will produce biased answers. Various types of bias have been identified by researchers including information, strategic, hypothetical, vehicle, and starting-point bias (Kerr and Sharp, 1986). However, an increasing number of studies indicate that, with careful design and implementation, many of these problems can be avoided and/or mitigated and reliable data generated (Cummings *et al.*, 1986; Mitchell and Carson, 1989). Attempts have been made to check the validity of survey methods by comparing the results from direct and indirect estimation techniques (Brookshire *et al.*, 1982; Cummings *et al.*, 1986; Smith *et al.*, 1986). The conclusion of Smith *et al.* is worth considering.

> "Judgement is an inevitable component of any empirical model of an economic process. It is also a part of the design and implementation of contingent valuation surveys. In the past economists have felt more comfortable with judgements applied in indirect methods rather than those involved in survey research. Our findings suggest that an understanding of the limitations in both types of methods is essential to interpreting results of comparative analyses. These results ... imply ... that benefit estimation ... is not a mechanical process. Judgement combined with sensitivity analysis and plausibility checks are likely to be more important to the quality of a resulting set of benefit estimates than strict reliance on methods based exclusively on observable behaviour" (p.289).

An alternative method to determine the accuracy of the CVM is to check results for repeatability. Loomis (1989) repeated a contingent valuation study after one year had elapsed, to determine whether the results generated by a sample drawn from the same population were comparable with the original results. The results from the two studies differed, but the differences were not statistically significant.

The judgement that survey methods are valuable has recently been acknowledged by the United States courts who have recognised that they provide the best available source of information on non-use values (Smith, 1990, p.198). In New Zealand, several applications of contingent valuation during the last decade have demonstrated its feasibility and usefulness, often in situations where no alternative evaluation method appears possible. However, studies to determine the validity and reliability of the method would also be very valuable in New Zealand.

CHAPTER 10

Conclusions

The objective of this publication has been to provide an understanding of the concept of option value and to determine its importance for policy formulation in New Zealand. Uncertainty exists in many situations where economists are asked to estimate the costs and benefits of alternative policies. These uncertainties are most evident in the area of environmental policy. A list of applied policy research areas relevant to New Zealand includes: the protection of endangered species, hazardous waste management, air pollution control, groundwater contamination, water resource development and pesticide use policy.

Where uncertainty exists, the policy analyst should use concepts and analytical techniques that survive continued challenge in the literature. Techniques that incorporate uncertainty into cost-benefit analysis, using subjective probability distributions of key parameters, miss the fact that individual welfare can be directly influenced by uncertainty. Moreover, the use of ECS as a welfare measure has found little support in the literature. In other words, the relationship between an individual's willingness to pay, or willingness to accept compensation, and uncertainty needs to be explicitly recognised in the valuation exercise. Option values focus attention on the individual as he or she evaluates alternatives under uncertainty.

Option value is an adjustment, positive or negative, that the individual makes to his or her expected surplus when confronted with demand and supply uncertainty. The concept of option price includes ECS and option value. Option price includes option value regardless of whether the latter is large, small, positive or negative. After lengthy debate in the literature the concept of option price is considered to be consistent with the *ex ante* compensation test which is appropriate when policy analysis is complicated by uncertain outcomes.

Progress has also been made in measuring the welfare effects of uncertainty. Although it is possible to measure ECS, option price and option value, researchers are well advised to concentrate on measuring option price, unless of course there are compelling reasons for measuring option value. Numerous studies have raised questions that are not consistent with the theoretical framework of consumer valuation; some have evaluated welfare measures using compensation tests that are inconsistent with the valuation perspective. Therefore, it is important that those undertaking applied research comprehend the uncertain situation confronting individuals and understand the economic concepts relevant to supplying decision makers with consistent, and accurate, estimates of welfare.

Over the past 25 years the contingent valuation method has been refined as progress has been made on the theoretical issues underpinning option value. Early estimates of option value were obtained from questionnaires that *inter alia* did not accurately characterise demand and supply uncertainty. Failure to appreciate the significance of the contingent market to respondents produced great variability in the magnitude of user values. Today, contingent valuation is clearly the superior valuation technique. Careful survey design and implementation will produce estimates of costs and benefits that can assist decision makers to formulate and implement policies aimed at improving welfare.

Option price is a more accurate measure of welfare than expected consumer surplus but the latter measure has been much more widely used in cost-benefit analysis to date. Both empirical and theoretical work have attempted to establish how important the divergence between option price and ECS is. The results from empirical studies to date have been ambiguous with some early studies suggesting that option value could be a very large fraction of ECS. However, one later, more carefully conducted study suggests that option value is of very small magnitude.

Theoretical analysis has established that option value can be of negative or positive sign. Theory also suggests that option value will be large only in a few circumstances. Option value is most likely to be of significant positive magnitude where, for cases of state-dependent preferences, individuals are strongly risk averse, the probability of demand for the good or service is low, and consumer surplus as a percentage of income is high. Unique goods and services such as national parks, important cultural and historic sites, and endangered species appear to be cases where option value is of significant magnitude.

Where demand uncertainty arises from uncertainty about future incomes and prices, option value can be negative for risk-averse individuals and ECS will give an overestimate of welfare effects of a project or policy.

Theoretical work may not make further progress in establishing the sign of option value, but the messages from the theoretical work should be carefully considered by analysts charged with conducting a cost-benefit analysis. Cost-benefit analysis in New Zealand should aim to use option price as a welfare measure, in those circumstances where option value is likely to be of significant magnitude. Acceptance of the practical superiority of option price over ECS is likely to occur only after the completion of several carefully conducted empirical studies demonstrating the feasibility of measuring option price and the significant magnitude of option value.

Experimental work is increasingly employed in economics to provide answers to questions about individuals' behaviour (Plott, 1991). In New Zealand, for example, experimental research has recently been completed by the Centre for Resource Management at Lincoln University, investigating the effects of varying types of information in CVM studies (Fahy and Kerr, 1991). New Zealand could complement carefully conducted cost-benefit studies that measure option price by adopting the advice of Bishop (1988) and conducting laboratory and field experiments to determine the role of uncertainty in influencing welfare.

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