Chapter 2

CONCEPTUAL FRAMEWORK FOR NONMARKET VALUATION

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1. INTRODUCTION

Serious practice of nonmarket valuation requires a working knowledge of the economic theory because it forms the basis for the explicit goals in any nonmarket valuation exercise. This chapter provides readers with the requisite theory to meaningfully apply the nonmarket valuation techniques.

To do so, I will (1) develop a model of individual choice that explicitly recognizes the public good nature of nonmarket goods. Using this model, I will (2) derive the basic welfare measures that nonmarket valuation studies attempt to measure. Moving toward a more specific framework, I will (3) examine how market behavior can be used to identify the basic welfare measures for nonmarket goods. I will also (4) provide a discussion of situations for which market demands are not sufficient to recover the basic welfare measures, cases of passive use value or visits to new recreation sites. From there, I will (5) discuss inter-temporal choice and nonmarket valuation, and finally nonmarket valuation under uncertainty.[1]

2. THEORETICAL MODEL OF NONMARKET GOODS

Nonmarket valuation is necessary and distinct from neoclassical price theory of market goods. The air quality in Boulder, the water quality of Colorado's lakes and streams, and the preservation of public lands are relevant examples of nonmarket goods. Each of these goods can change due to society's choices, but individuals may not unilaterally choose their most preferred level of air quality, water quality, or acreage of preserved public lands. In addition to being outside of the choice set of any individual, these examples have the feature that everyone experiences the same level of the good. Citizens of Boulder experience the same level of local air quality; citizens of Colorado experience the same level of water quality in the state's lakes and streams; and finally the level of preserved public lands is shared by all. Rationed, common level goods serve as our point of departure for standard neoclassical price theory in developing the theoretical framework.

The basic premise of neoclassical economic theory is that people have preferences over goods, in our case both market and nonmarket goods. Without regard to the costs, each individual is assumed to be able to order bundles of goods in terms of desirability, resulting in a complete preference ordering. The fact that each individual can preference order bundles forms the basis of choice. The most fundamental element of economic theory is the preference ordering, more simply the desires of the individual, not money. Money plays an important role since individual have a limited supply of money to buy many, but not all, of the things they want. Economic theory is silent with regard to motivation. An individual may desire improved air or water quality or the preservation of an endangered species for any reason including for personal use, bequests to future generations, or simply for the existence of the resource. As Becker (1993) offers that the reasons for enjoyment of any good can be "selfish, altruistic, loyal, spiteful, or masochistic." Economic theory provides nearly complete flexibility for accommodating competing systems of values

Preference ordering can be represented through a utility function defined over goods. For our purposes, $X = [x_1, x_2, \ldots, x_n]$ denotes a list or vector of all of the levels for the n market goods that the individual chooses. The k nonmarket goods are similarly listed as $Q = [q_1, q_2, \ldots, q_k]$. The utility function assigns a single number, $U(X, Q)$, for each bundle of goods (X, Q). For any two bundles, (X^A, Q^A) and (X^B, Q^B), the respective numbers assigned by the utility function are such that $U(X^A, Q^A) > U(X^B, Q^B)$ if and only if (X^A, Q^A) is preferred over (X^B, Q^B). The utility function is thus a complete representation of preferences.[2]

Money enters the process through scarcity and, in particular, scarcity of money to spend on obtaining the things we enjoy. For market goods, individuals choose the amount of each good to buy based on preferences, the relative prices of the market goods $P = [p_1, p_2, . . ., p_n]$, and available income. Given this departure point, the nonmarket goods are rationed in the sense that individuals may not unilaterally choose the level of these goods.[3] The basic choice problem is how to obtain the highest possible utility level when spending income *y* towards the purchase of market goods is subject to a rationed level of the nonmarket goods.

$$\max_{X} U(X, Q) \quad s.t. \quad P \cdot X \le y, \quad Q = Q^0 \tag{1}$$

There are two constraints that people face in (1). First, the total expenditure on market goods cannot exceed income,[4] and second, the levels of the nonmarket goods are fixed.[5] The *X* that solves this problem then depends on the level of income (y), the prices of all of the market goods (P), and the level of the rationed, nonmarket goods (Q). For each market good, we have an optimal demand function that depends on these three elements, $x_i^* = x_i(P, Q, y)$; the vector of optimal demands can be written similarly, $X^* = X(P, Q, y)$ where the vector now lists the demand function for each market good. If we plug the set of optimal demands into the utility function, we obtain the indirect utility function, $U(X^*, Q) = v(P, Q, y)$. Because the demands depend on prices, the levels of the nonmarket goods, and income, the highest obtainable level of utility also depends on these elements.

As the name suggests, demand functions provide the quantity of goods demanded at a given price vector and income level. Demand functions also can be interpreted as marginal value curves since consumption of goods occurs up to the point where marginal benefits equal marginal costs. For this reason, demand has social significance.

2.1 Compensating and Equivalent Welfare Measures

Policies or projects that provide nonmarket goods often involve costs. We may assign value to these policies or projects in order to assess whether the benefits justify the costs. For example, consider a policy intended to improve the water quality of Boulder Creek, a stream that runs through my hometown of Boulder, Colorado. I care about this stream because I jog along its banks and enjoy the wildlife that it supports, including the trout that my daughters may catch when they are lucky. To pay for this clean-up, the prices of market goods might change due to an increase in sales tax and/or I might be asked to pay a lump-sum fee. Two basic measures of value , which are standard fare in welfare economics, may be used to assess the benefit of cleaning up Boulder Creek. The first is the amount of income that I would give up after the policy has been implemented that would exactly return my utility to the status quo utility level. This measure is the *compensating* welfare measure, which I will refer to as C. Letting 0 superscripts denote the initial, status quo, conditions and 1 superscripts denote the new conditions provided by the policy, define C using the indirect utility function.

$$v(P^0, Q^0, y^0) = v(P^1, Q^1, y^1 - C) \tag{2}$$

The basic idea behind C is that if I give up C with the changes, then I am back to my original utility. C could be positive or negative depending upon how much prices increase and/or the size of any lump sum tax that I pay. If costs are less than C and the policy is implemented, then I am better off than before the policy. If costs are more than C, I am worse off.

The second basic welfare measure is the amount of additional income that I would need with the initial conditions to obtain the same utility as after the change. This is the *equivalent* welfare measure, referred to as E, and is defined as follows.

$$v(P^0, Q^0, y^0 + E) = v(P^1, Q^1, y^1) \tag{3}$$

The two measures differ by the implied assignment of property rights. For the compensating measure, we are recognizing the initial utility level as the basis of comparison. For the equivalent measure, we are recognizing the subsequent level of utility as the basis. Whether one should consider the compensating welfare measure or the equivalent welfare measure as the appropriate measure depends on the situation. Suppose that we are considering a new policy intended to improve Boulder Creek water quality. In this case, the legal property right is the status quo; therefore, we should use the compensating welfare measure. There are, however, instances when the equivalent welfare measure is conceptually correct. Returning to the water quality example, the Clean Water Act provides minimum water quality standards. In essence, the Act assigns a property right to the standard. If water quality had declined below the standard and we are considering a project that would restore quality to this minimum standard, then the equivalent welfare measure is the appropriate measure. Both conceptual and practical matters should guide the choice between the compensating and equivalent welfare measure.[6]

2.2 Duality and the Expenditure Function

I have so far used the indirect utility function to describe the basic welfare measures used in economic policy analysis. To more easily discuss and analyze specific changes, we can equivalently use the expenditure function to develop our welfare measures. The indirect utility function represents the highest level of utility obtainable when facing prices P, nonmarket goods Q, and income y. A necessary condition for utility maximization is that we spend our income in a least-cost manner. To illustrate this, suppose that my market good purchases are facing prices P and nonmarket goods Q. I obtain a utility level of U^0. Now suppose that I am not minimizing my expenditures and U^0 could be obtained for less money. If this were true, I would not be maximizing my utility since I could spend less on U^0 and use the remaining money to buy more market goods and thus obtain a utility level higher than U^0. This reasoning is the basis of what we refer to in microeconomics as the dual problem. Instead of looking at maximizing utility subject to the budget constraint, we consider the dual problem of minimizing expenditures subject to obtaining a given level of utility. The expenditure minimization problem is stated as follows.

$$\min_{X} P \cdot X \quad s.t. \quad U(X, Q) \geq U^0, \quad Q = Q^0 \tag{4}$$

The solution to this problem is the set of compensated or Hicksian demands which are a function of prices, nonmarket goods levels, and level of utility, $X^* = X^h(P, Q, U)$. The dual relationship between the ordinary demands and the Hicksian demands is that $X(P, Q, y) = X^h(P, Q, U)$ when either $U = v(P, Q, y)$ in the expenditure minimization problem or $y = P{\cdot}X^h(P, Q, U)$ in the utility maximization problem. As the phrase duality suggests, these relationships represent two views of the same choice process. The important conceptual feature of the compensated demands is that utility is fixed at some specified level of utility, which relates directly to our compensating and equivalent welfare measures. For the expenditure minimization problem, the expenditure function, $e(P, Q, U) = P{\cdot}X^h(P, Q, U)$, takes the place of the indirect utility function.

It is worth stressing that the expenditure function is the ticket to understanding welfare economics. Not only does the conceptual framework exactly match the utility-constant nature of welfare economics, the expenditure function itself has very convenient properties. In particular, the expenditure function approach allows us to a decompose a policy that changes multiple goods or prices into a sequence of changes which will be shown below to provide powerful insight into our welfare measures.

I have so far introduced the broad concepts of compensating and equivalent welfare measures. Hicks (1943) developed the compensating and equivalent measures distinctly for price and quantity changes and named them respectively as the price compensating/equivalent variation for changes in prices and the quantity compensating/equivalent variation for quantity changes. These two distinct measures are now typically referred to as the compensating/equivalent variation for price changes and the compensating/equivalent surplus for quantity changes. It is easy to develop these measures using the expenditure function, particularly when one understands the terms equivalent and compensating.

Before jumping directly into the variations and surpluses, I want to discuss income changes. Income changes can also occur as a result of policies, and so we deal with changes in income first. For example, regulating the actions of a polluting firm may decrease the demand for labor and result in lower incomes for workers.

2.3 The Treatment of Income Changes

Let $U^0 = v(P^0, Q^0, y^0)$ represent the status quo utility level and $U^1 = v(P^1, Q^1, y^1)$ the utility level after a generic change in income, prices, and/or nonmarket goods. Our compensating and equivalent measures introduced above are kept here, but I have added a change in income. The two measures are defined by the fundamental identities as follows.

(5)
$$v(P^0, Q^0, y^0) = v(P^1, Q^1, y^1 - C)$$
$$v(P^0, Q^0, y^0 + E) = v(P^1, Q^1, y^1)$$

We can also represent *C* and *E* using the expenditure function.

(6)
$$C = e(P^1, Q^1, U^1) - e(P^1, Q^1, U^0)$$
$$E = e(P^0, Q^0, U^1) - e(P^0, Q^0, U^0)$$

To determine how to handle income changes, I need to rewrite *C* and *E* in more workable forms. In expenditure terms, $y^0 = e(P^0, Q^0, U^0)$, $y^1 = e(P^1, Q^1, U^1)$, and $y^1 = y^0 + y^1 - y^0$. By creatively using these identities, I can rewrite *C* and *E* as follows.

(7)
$$E = e(P^0, Q^0, U^1) - e(P^1, Q^1, U^1) + (y^1 - y^0)$$
$$C = e(P^0, Q^0, U^0) - e(P^1, Q^1, U^0) + (y^1 - y^0)$$

The new form shows that for *C*, we value the changes in prices and nonmarket goods at the initial utility level and then consider the income change. For *E*, we value the changes in prices and nonmarket goods at the post-change utility level and then consider income change. The generalized compensated measure is subtracted from income under the subsequent conditions (equation 2), while the generalized equivalent measure is added to income under the initial conditions (equation 3). How we value the changes in prices and nonmarket goods is the next question.

2.4 Variation Welfare Measures for a Change in Price *i*

Suppose we are considering a policy that only provides a price decrease for good *i*, $p_i^0 > p_i^1$. Hicks referred to the compensating welfare measure for a price change as compensating variation (CV) and the equivalent welfare measure as equivalent variation (EV). Since a price decrease makes the consumer better off, both measures are positive. P_{-i} refers to the price vector left after removing p_i.

(8) $$CV = e(p_i^0, P_{-i}^0, Q^0, U^0) - e(p_i^1, P_{-i}^0, Q^0, U^0)$$

(9) $$EV = e(p_i^0, P_{-i}^0, Q^0, U^1) - e(p_i^1, P_{-i}^0, Q^0, U^1)$$

Using Roy's identity, and the fundamental theorem of calculus, compensating and equivalent variations can be expressed as the area under the Hicksian demand curve between the initial and subsequent price.[7] Here s represents p_i along the path of integration.

(10) $$\begin{aligned} CV &= e(p_i^0, P_{-i}^0, Q^0, U^0) - e(p_i^1, P_{-i}^0, Q^0, U^0) \\ &= \int_{p_i^1}^{p_i^0} x_i^h(s, P_{-i}^0, Q^0, U^0)\, ds \end{aligned}$$

(11) $$\begin{aligned} EV &= e(p_i^0, P_{-i}^0, Q^0, U^1) - e(p_i^1, P_{-i}^0, Q^0, U^1) \\ &= \int_{p_i^1}^{p_i^0} x_i^h(s, P_{-i}^0, Q^0, U^1) ds \end{aligned}$$

For the price change, compensating variation is simply the area under the Hicksian demand curve evaluated at the initial utility level and the two prices. Similarly, equivalent variation is simply the area under the Hicksian demand curve evaluated at the new utility level and the two prices. Figure 1 depicts these two measures for the price change.

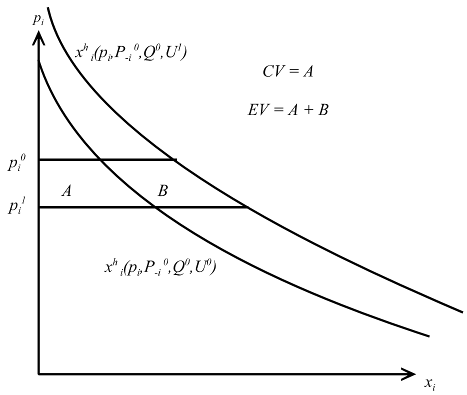

Figure 1. Compensating and Equivalent Variations for a Decrease in p_i

A few issues regarding the welfare analysis of price changes deserve mention. First, I have only presented a single price change. Multiple price changes are easily handled using a compensated framework that simply decomposes a multiple price change into a sequence of single price changes (Braeutigam and Noll 1984). I will provide an example of how to do this in the discussion of weak complementarity below. Second, the area under the ordinary (uncompensated) demand curve and between the prices is often used as a proxy for either compensating or equivalent variation. Willig (1976) has shown that in many cases this approximation is quite good, depending on the income elasticity of demand and the size of the price change. Hausman (1981) offered one approach to deriving the exact Hicksian measures from ordinary demands. Vartia (1983) offered another that uses numerical methods for deriving the exact Hicksian measures. While both methods for deriving the compensated welfare measures from ordinary demands are satisfactory, Vartia's method is very simple. Finally, we also need to consider price increases, which are conceptually the same except that the status quo price is now the lower price, $P^0 < P^1$. Both welfare measures here are negative. In the case of compensating variation, we take away a negative amount, *i.e.* give money, because the new price level makes me worse off. Similarly we would have to give up money at the old price in order to equate utility with utility at the new price, which is equivalent to saying we have a negative equivalent variation.

2.5 Welfare Measures for a Change in Nonmarket Good *j*

Now suppose we are considering an increase in nonmarket good q_j. Recall that our compensating and equivalent measures are referred to as compensating surplus (CS) and equivalent surplus (ES). The expenditure function representation of these is given as follows.

$$CS = e(p^0, Q^0, U^0) - e(p^0, Q^1, U^0) \tag{12}$$

$$\begin{aligned} CS &= e(P^0, q_j^0, Q_{-j}^0, U^0) - e(P^0, q_j^1, Q_{-j}^0, U^0) \\ &= \int_{q_j^0}^{q_j^1} p_i^v(P^0, s, Q_{-j}^0, U^0)\, ds \end{aligned} \tag{13}$$

$$ES = e(p^0, Q^0, U^1) - e(p^0, Q^1, U^1) \tag{14}$$

Using the properties of the expenditure function, one can rewrite the quantity compensating and equivalent variations in an insightful form. Maler (1974) showed that the derivative of the expenditure function with respect to nonmarket good *j* is simply the negative of the inverse Hicksian demand curve for nonmarket good *j*. This derivative equals the negative of the virtual price, *i.e.* shadow value, of nonmarket good *j*. Again applying the fundamental theorem of calculus, we can rewrite the surplus measures in terms of this shadow value. Note that the properties of the integral we used to change the order of the integration limits, which then cancels out the negative factor.

Similar to the notation for price changes, Q_{-j} refers to the price vector left after removing q_j, and s represents q_j, along the path of integration.

(15)
$$ES = e(P^0, q_j^0, Q_{-j}^0, U^1) - e(P^0, q_j^1, Q_{-j}^0, U^1) = \int_{q_j^0}^{q_j^1} p_i^v(P^0, s, Q_{-j}^0, U^1)\, ds$$

Figure 2 graphs the compensating and equivalent surpluses for this increase. The graph looks similar to Figure 1 except that the change is occurring in the quantity space as opposed to the price space.

Figure 2. Compensating and Equivalent Variations for an Increase in q_i

In thinking about compensating/equivalent surpluses as opposed to the variations, it is useful to remember what is public and what is private. In the case of market goods, prices are public and the demand for the goods varies among individuals. For our nonmarket goods, the levels are public and shared by all while the marginal values vary among individuals. These rules of thumb help to differentiate between the graphic representations of compensating/equivalent variations and surpluses.

2.6 Compensating and Equivalent Variations, Willingness to Pay, and Willingness to Accept

Provided that we can agree on what constitutes the initial levels of prices and nonmarket goods, then our compensating and equivalent welfare measures are clearly defined and hopefully by now easy to understand. Two other terms, willingness to pay (WTP) and willingness to accept (WTA) compensation, are often used as substitute names for either the compensating measures or the equivalent measures. WTP is typically associated with a desirable change and WTA compensation is associated with a negative change. Consider Table 1 for a price change.

Table 1. (Freeman 1993, pg 58)

Welfare Measure	Price Increase	Price Decrease
EV - Implied property right in the change	WTP to avoid	WTA to forgo
CV - Implied property right in the status quo	WTA to accept	WTP to obtain

As the table suggests, one needs to be explicit about what you are paying for when using WTP and one needs to be explicit about what you are being compensated for when using WTA. In cases where utility changes are unambiguously positive or negative, the WTP/WTA terminology works well. However, when we have combinations of desirable and undesirable changes, such as an increase in water quality accompanied by an increase in sales taxes on market goods, then WTP and WTA are less useful terms. This is true because if the policy as a whole is bad $(U^0 > U^1)$, then the compensating welfare measure is WTA and the equivalent welfare measure is WTP to avoid the policy. If the policy as a whole is good $(U^0 < U^1)$, then the compensating welfare measure is WTP to obtain the policy and the equivalent welfare measure is WTA forgoing the policy. The situation could result in mixed loses and gains leading us to measure WTA for losers and WTP for gainers the WTP/WTA terminology. For example, reintroduction of the wolf in Colorado may make conservationists better off while some ranchers are made worse off. Using equivalent or compensating welfare measures, we refer to one measure for losers and gainers.

These concepts refer to gains and losses at the individual level. As discussed in Chapter 1, there are different approaches to aggregating information from individuals to make collective choices. The Kaldor-Hicks potential compensation test is the most widely used approach to aggregating compensating and equivalent welfare measures.

3. IMPLICIT MARKETS FOR ENVIRONMENTAL GOODS

By definition, we do not explicitly purchase nonmarket goods. We do, however, purchase other goods for which demands are related to nonmarket goods. For example, my choice of where to recreate may depend on the environmental quality of the sites under consideration. Furthermore, environmental quality can influence my choice of which community to live in or which house to buy once I have decided on the community. These market links to nonmarket goods makes it possible to infer values for the demand revealed through these purchases. The specific nonmarket valuation techniques used to infer these values, called revealed preference methods, are described in Chapters 8 through 11. This section reviews some of the concepts related to inferring environmental values from market purchases.

3.1 Price Changes and Environmental Values

Suppose we are increasing nonmarket good q_1, we wish to measure the monetary value for this change, and that we determine compensating surplus to be the appropriate measure. Using the expenditure function, the only argument that changes is q_1. Q_{-1} is the vector left after removing the first element of Q.

(16) $$CS = e(P^0,\, q_1^0,\, Q_{-1}^0,\, U^0) - e(P^0,\, q_1^1,\, Q_{-1}^0,\, U^0)$$

Now I want to introduce an arbitrary price change along with this quantity change by adding and subtracting two different terms. I have not changed the size of the compensating surplus.

$$
\begin{aligned}
CS = {} & e(P^1, q_1^1, Q_{-1}^0, U^0) - e(P^0, q_1^1, Q_{-1}^0, U^0) \\
& - [e(P^1, q_1^0, Q_{-1}^0, U^0) - e(P^0, q_1^0, Q_{-1}^0, U^0)] \\
& + e(P^1, q_1^0, Q_{-1}^0, U^0) - e(P^1, q_1^1, Q_{-1}^0, U^0)
\end{aligned}
\tag{17}
$$

The second and fourth terms are the original terms in (17) and the other four are the "zero" terms. Note the arrangement of the terms. The first line is the value of the price change at the new level of q_1. The second line is the negative of the value of the price change at the initial level of q_1. The last line is the value of the change in q_1 at the new price level. If a special condition referred to as weak complementarity is satisfied, this arrangement is useful and forms the basis for the travel cost method presented in Chapter 9.

3.2 Weak Complementarity

Suppose that the compensated demand for market good one (x_1) depends upon the level of q_1 in a marginally positive way, i.e. the demand curve shifts out as q_1 increases. Further suppose that if consumption of this market good is zero, the marginal value for the change in q_1 is zero. Maler (1974) referred to this situation as weak complementarity. Now turning back to the way compensating surplus was rewritten in (17), suppose that the change in price was from the original price level to the price that chokes off demand for this weakly complementary good. This choke price is designated as $\hat{p}_1$ below.

$$
\begin{aligned}
CS = {} & e(\hat{p}_1, P_{-1}^0, q_1^1, Q_{-1}^0, U^0) - e(p_1^0, P_{-1}^0\ q_1^1, Q_{-1}^0, U^0) \\
& - [e(\hat{p}_1, P_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(p_1^0, P_{-1}^0, q_1^0, Q_{-1}^0, U^0)] \\
& + e(\hat{p}_1, P_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(\hat{p}_1, P_{-1}^0, q_1^1, Q_{-1}^0, U^0)
\end{aligned}
\tag{18}
$$

By definition, demand for our weakly complementary good is zero at $\hat{p}_1$,so the last line of equation 18 equals zero. Now our compensating surplus is simply the change in total consumer surplus for the weakly complementary good.

(19)
$$
\begin{aligned}
CS &= e(\hat{p}_1,\ P^0_{-1},\ q^1_1,\ Q^0_{-1},\ U^0)\ -\ e(p^0_1,\ P^0_{-1},\ q^1_1,\ Q^0_{-1},\ U^0)\\
&\quad -\ [e(\hat{p}_1,\ P^0_{-1},\ q^0_1,\ Q^0_{-1},\ U^0)\ -\ e(\hat{p}_1,\ P^0_{-1},\ q^0_1,\ Q^0_{-1},\ U^0)]\\
&= \int_{p^0_1}^{\hat{p}_1} x_1^h(s,\ P^0_{-1}\ q^1_1,\ Q^0_{-1},\ U^0)ds\ -\ \int_{p^0_1}^{\hat{p}_1} x_1^h(s,\ P^0_{-1},\ q^0_1,\ Q^0_{-1},\ U^0)ds
\end{aligned}
$$

Weak complementarity is convenient because valuing the change in the nonmarket good is possible by valuing the change in consumer surplus from the weakly complementary good. Figure 3 graphically depicts compensating surplus for this weakly complementary good.

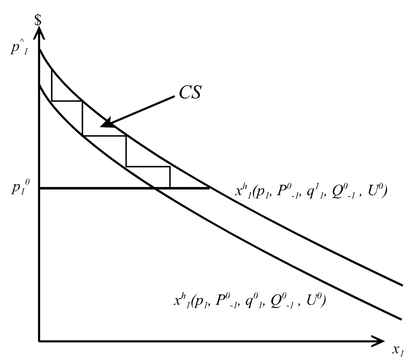

Figure 3. Weakly Complementarity of Market Good x_1 and CS for a Change in Nonmarket Good q_1

Consumption of several goods might need to be zero in order for the marginal value of q_1 to equal zero. An example is increasing the water quality at two sites along a river. The value of improving water quality might be zero if trips to both sites were zero, a joint weak complementarity condition. These concepts are similar to those I have so far presented. The difference is the way we deal with the sequence of price changes. The final line in the analog to (19) would still equal zero. However, we have multiple prices to consider. Let me give a simple example of how prices of two goods would need to be adjusted. Suppose that if demand for market good one and two are zero, then the marginal value for the change in q_1 equals zero. Compensating surplus is then given as follows. Similar to earlier notation, $P^0_{-1,-2}$ is the price vector formed by removing the first and second elements of P^0.

$$
\begin{aligned}
CS = & \int_{p_1^0}^{\hat{p}_1} x_1^h(s,\ P^0_{-1},\ q_1^1,\ Q^0_{-1},\ U^0)ds \\
& - \int_{p_1^0}^{\hat{p}_1} x_1^h(s,\ P^0_{-1},\ q_1^0,\ Q^0_{-1},\ U^0)ds \\
& + \int_{p_2^0}^{\hat{p}_2} x_2^h(\hat{p}_1,\ s,\ P^0_{-1,-2}\ q_1^1,\ Q^0_{-1},\ U^0)ds \\
& - \int_{p_2^0}^{\hat{p}_2} x_1^h(\hat{p}_1,\ s,\ P^0_{-1,-2}\ q_1^0,\ Q^0_{-1},\ U^0)ds
\end{aligned}
\tag{20}
$$

Compensating surplus is given by the change in consumer surplus resulting from the increase in q_1 for the two goods. For the first good, the change in consumer surplus is conditioned on all of the other prices being held at the original level, P^0_{-1}. For the second good, the change in consumer surplus is conditioned on the choke price of the first good, $\hat{p}_1$, and the original price for the remaining market goods, $P^0_{-1,-2}$. If we had a third good, the change in consumer surplus for the third good would be conditioned on the choke prices of goods one and two. This adjustment would be necessary for measuring changes in consumer surplus for any sequence of price changes, not just choke prices. The order of the price changes does not matter as long as we condition on the other prices correctly (Braeutigam and Noll 1984).

Before moving onto inference for marginal values, I want to briefly discuss two issues related to weak complementary goods. First, we need not rule out a market price other than the choke price for which we obtain the condition that the marginal value of our market good is zero.[8] Any price that results in this condition allows the compensating surplus to be derived from the compensated market demands. Though we cannot rule these possibilities out, a solid case exists for this particular selection of the price change. The techniques discussed in this section will handle any such price. A second issue is the impact of incorrectly assuming weak complementarity. The last term that vanishes under weak complementarity will be positive if we incorrectly assume weak complementarity. In this case, the value inferred from the good (incorrectly) assumed to be weakly complementary will simply bound compensating surplus from below.

3.3 Household Production Framework

A slightly different approach to that presented above is the household production framework.[9] The household production framework is the basis for the defensive behavior approach to nonmarket valuation described in Chapter 11. Suppose we are interested in determining the marginal value of a single nonmarket good q_j. The household production framework posits a production relationship between a consumption goods x_p and q_j. The good produced in this process is a final product that the consumer values. Let us partition the vector$X$ into $[X_1, x_p]$, where x_p is a good produced by the individual according to the a production process $x_p = f(I, q_j)$. I is a marketed production input, and X_1 is the vector of market goods consumed. Assuming that q_j, enters the choice problem only through production of x_p, the utility maximization problem is as follows.

$$(21) \qquad \max_{X_1,\, I} U(X_1, x_p) \quad s.t. \quad p_1 \cdot X_1 + p_I \cdot I \le y, \quad q_j = q_j^0, \quad x_p = f(I, q_j)$$

The necessary conditions for this maximization problem imply two important equations that involve the marginal value of additional income, λ, and the marginal value (virtual price) of additional q_j given by $p_{q_j}^v$.

(22) $$\frac{\partial U}{\partial x_p} \cdot \frac{\partial f}{\partial I} = \lambda \cdot p_I \qquad \frac{\partial U}{\partial x_p} \cdot \frac{\partial f}{\partial q} = p_{q_j}^v \cdot \lambda$$

From these two equations, we can solve for the marginal value of q_j.

(23) $$p_{q_j}^v = p_I \cdot \frac{\left(\frac{\partial f}{\partial q}\right)}{\left(\frac{\partial f}{\partial I}\right)}$$

Thus, we can derive the marginal value of q_j from the price of the input and the marginal rate of transformation between the input and q_j. The desirable property of this technique is that we do not have to model preferences. Of course we still have to model the production process. Moving away from a single input and a single produced good quickly complicates the model. For one, we need to model preferences since marginal utilities come into play. Thus we need to model the production process *and* consumer preferences thus creating an additional layer to what we have already presented above in the basic framework.[10]

3.4 The Hedonic Concept[11]

Some goods we consume can be viewed as bundles of attributes. For example, houses have distinguishing attributes such as square footage, number of bedrooms, location, and environmental attributes. Open space is a publicly owned good that is accessible to all. Being close to open space is, for some, a valuable attribute. The closer houses are to open space, the higher the price for houses that are otherwise identical. Given this price gradient, purchasers of homes can buy location relative to open space up to the point where the marginal cost of moving closer equals the marginal benefit. Hence we have an implicit market in this attribute because the home price varies according to the attribute proximity to open space. This concept underlies the hedonic nonmarket valuation technique described in Chapter 10. Other examples of attributes in the housing market are air quality, proximity to busy streets, and proximity to power lines. Environmental risk is an attribute of jobs, which are objects of choice that implicitly offer us the chance to trade off pay and on-the-job risk of injury or exposure to toxins. The important feature of the hedonic model is that an implicit market exists for attributes of goods such as proximity to open space or job risk that are not explicitly traded in markets.[12]

In the case of the home purchase, the idea is that the consumer purchases environmental quality through the house. Utility still depends on the consumption of market goods X and nonmarket goods Q, but now certain aspects of Q can be thought of as being chosen. It is important to recognize levels of rationing. For example, I do not individually purchase open space; thus, the quantity of Q is fixed. I can, however, purchase a home closer to the open space that is available. For the case of air quality, the quality gradient is fixed so far as the individual is concerned. A resident of Los Angeles cannot unilaterally affect this. The resident of Los Angeles can choose a house based on where it falls along the air quality gradient. She can care a great deal about the gradient itself in ways other than her choice of housing. For example she can live near the beach, which has relatively good air quality, and yet be subjected to really poor air quality at work downtown. Similarly I can locate near the north Boulder open space and yet care a great deal about whether the Boulder County purchases another tract of land in south Boulder. The point here is that Q can enter my utility for life at home and separately for other purposes.

The basic approach to the hedonic method is that the house is really a bundle of attributes. Since other people also care about these attributes, they are scarce and valuable. Although we pay a bundled price for the house, we are paying for the individual attributes. A way to model things on the consumer side is to partition both market goods, $X = [X_1, X_2]$ and nonmarket goods, $Q = [Q_1, Q_2]$. The second vector in both the market and nonmarket goods partition are those attributes selected through the housing purchase. The total price of the house is a function of these attributes, $p_h(X_2, Q_2)$. The maximization problem follows.

$$\max_{X,\, I} \; U(X_1,\, X_2,\, Q_1,\, Q_2) \tag{24}$$

$$s.t. \quad p_1 \cdot X_1 + p_h(X_2,\, Q_2) \le y, \quad Q_1 = Q_1^0$$

The important feature is that the consumer chooses the levels of Q_2 through the house purchase up to the point where the marginal benefit equals marginal cost. In particular, the equal marginal rate of substitution condition, called the equimarginal condition, is satisfied for any of the individual elements in Q_2 and the individual market goods in either X_1 or X_2.

$$\frac{\left(\frac{\partial U}{\partial q_j}\right)}{\left(\frac{\partial U}{\partial x_i}\right)} = \frac{\left(\frac{\partial p_h}{\partial q_j}\right)}{\left(\frac{\partial p_h}{\partial x_i}\right)} \quad q_j \in Q_2, \quad x_i \in X_2$$

(25)

$$\frac{\left(\frac{\partial U}{\partial q_j}\right)}{\left(\frac{\partial U}{\partial x_i}\right)} = \frac{\left(\frac{\partial p_h}{\partial q_j}\right)}{p_i} \quad q_j \in Q_2, \quad x_i \in X_1$$

As in the case for market goods, the combined marginal substitution relationships conceptually yield a marginal substitution curve, referred to as the bid function for the individual. Conversely, sellers typically are trying to get the most money possible for their houses. The price function, $p_h(X_2,\, Q_2)$, is the resulting equilibrium from the interaction of buyers and sellers. Estimating the price function using demand data provides information on the marginal values of Q_2. Additional structure will allow the estimation of the bid function which can then be used to value non-marginal changes.

3.5 When Markets Will Not Do

The concepts outlined in the earlier sections involve the use of observable market behavior to infer either the marginal value of nonmarket goods or the value for a discrete change in the nonmarket goods. All of these methods require an identifiable link between the nonmarket goods and some subset of the market goods. Furthermore, there also must be sufficient variation in the prices of the market goods and the quantities of the nonmarket goods accompanying the observed transactions to be able to statistically identify these relationships. The concepts above form the basis for revealed preference techniques: travel cost/recreational demand modeling, household production function modeling, and the hedonic price method.

Using market data to infer the value of a nonmarket good requires that values can only be inferred for individuals who used the nonmarket good, but there are cases when the demand link is unidentifiable for some individuals. No identifiable link for some people does not mean that they do not value the nonmarket good. Value for these individuals for which there is no identifiable or estimable link is referred to as non-use value or passive use value. Passive use value is the legal term used by the U.S. Federal Court of Appeals in an influential court case, *Ohio v. U.S. Department of Interior*, that gave legal standing to the concept. Drawing on earlier work from Carson, Flores, and Mitchell (1999), a brief overview of how this concept evolved follows.

In a highly influential article, Krutilla (1967) suggested that revealed preference techniques may not accurately measure societal values. The strength of his argument came through example; the paper provides no theory. Using unique resources, such as the Grand Canyon, and considering irreversible changes, Krutilla makes a number of important points.[13] First, demand for the environment has dynamic characteristics that imply value for potential use, though not current use, and that trends for future users need to be explicitly recognized in order to adequately preserve natural areas.[14] Second, some individuals may value the environment for its mere existence. Krutilla gave the example of the "spiritual descendants of John Muir, the current members of the Sierra Club, the Wilderness Society, National Wildlife Federation, Audubon Society and others to whom the loss of a species or a disfigurement of a scenic area causes acute distress and a sense of genuine relative impoverishment." Third, bequest of natural areas to future generations may be a motive for current nonusers to value preservation, particularly since given the dynamic characteristics mentioned earlier, preserving natural areas effectively provides an estate of appreciating assets. These examples obviously struck a chord with many economists. Methods and techniques were developed to formally describe the phenomena mentioned by Krutilla and to measure the associated economic value.[15]

Measuring passive use values and using them in policy analysis, particularly natural resource damage assessment, has been controversial. Much of the problem stems from the fact that passive use values, by implied definition, cannot be measured from market demand data. Economics, as a discipline, places considerable emphasis on drawing inferences regarding preference from revealed action. However, stated preference methods such as contingent valuation and the attribute-based stated preference methods discussed in Chapters 5, 6, and 7 are the only viable alternatives for measuring passive use values. These stated preference methods draw inference from hypothetical tradeoffs. From these hypothetical tradeoffs we can at least hope to learn about preferences of individuals who hold passive use values. However given the economics profession's preference for inference from actual choices, the considerable skepticism regarding passive use values is understandable. Skepticism can occur on two levels. The first level of skepticism involves the measurement of passive use values because of the need to use stated-preference techniques. The second level involves the idea of whether or not passive use values even exist. The second position is fairly extreme, and I can reject this notion based on my own preferences. The former concern is valid and plenty of discussion exists in the literature.[16]

In this section, I will discuss how passive use values have been viewed conceptually. While my discussion will focus on compensating surplus, the issues also apply to equivalent surplus. Recall the decomposition of compensating surplus into the value of a price change, the new price being the choke price, and the value of the quantity change at the higher price level. Weak complementarity called for the final term to equal zero. McConnell (1983) and Freeman (1993), define passive use value as this last term.

$$
\begin{aligned}
CS = {} & e(\hat{p}_1, p_{-1}^0, q_1^1, Q_{-1}^0, U^0) - e(p_1^0, p_{-1}^0\ q_1^1, Q_{-1}^0, U^0) \\
& - [e(\hat{p}_1, p_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(p_1^0, p_{-1}^0, q_1^0, Q_{-1}^0, U^0)] \\
& + PUV
\end{aligned}
\tag{26}
$$

This definition does not have much practical appeal because we could choose any good that is not a necessary good, measure the value from the first two lines of (26) and end up with a measure of passive use value. Since we could do this for each good that is not a necessary good or any combination of goods in this category, we could derive multiple measures of passive use value.

Another conceptual definition was suggested by Hanemann (1995). Hanemann had a specific form of utility in mind, $U(X, Q) = T\,[g(X, Q), Q]$. This functional form suggests that choices of market goods will be influenced by Q and so market demand data could reveal the part of the relationship involving $g(X, Q)$, but not the part where Q enters directly.[17] Hanemann defines passive use value and use value according to the following two identities.

$$T[g(X(P, Q^0, y - PUV), Q^1] = T[g(X(P, Q^0, y)), Q^0] \tag{27}$$

$$T[g(X(P, Q^1, y - PUV - UV), Q^1] = T[g(X(P, Q^0, y)), Q^0] \tag{28}$$

The definitions implied by (26) and by (27) together with (28) decompose compensating surplus into two parts for which the sum of the parts equals the whole. Intuitively Hanemann's definition works in reverse of the decomposition in (26). Because the same preferences can be defined differently, passive use values is a somewhat tenuous theoretical concept.[18] Furthermore, neither definition is easy to implement since the first decomposition requires one to choose the market goods for which demand is choked. Using separate measurement, it is difficult to if not impossible to elicit either of these concepts to subjects in a stated preference study.

Carson *et. al*. (1999) provided a definition based on methodological considerations. "Passive-use values are those portions of total value that are unobtainable using indirect measurement techniques which rely on observed market behavior."[19] This definition was conceived with the researcher in mind as opposed to a theoretical foundation. Revealed preference techniques can miss portions of value because of the form of preferences such as those used in the Hanemann definition. We are typically after compensating or equivalent surplus, also referred to as total value in this literature. The definition implies that passive use value is the residual based on what is available. Practically and conceptually passive use value is not unique. The important social issue is the need to incorporate the values of all of those who value the nonmarket good.

To do so requires us, at times, to turn to stated preference techniques if we believe that passive use values are likely to be decisive.

4. NONMARKET VALUES IN A DYNAMIC ENVIRONMENT

Models of inter-temporal choice abound in economics. Most models assume that utility across time periods is represented by a sum of utility functions from each of the time periods. This sum involves a time preference component that is typically assumed to be the discount factor, $\beta = 1/(1 + r)$.

(29) $$U = \sum \beta^t u(X_t, Q_t)$$

The time horizon, T, can be either finite or infinite. The analog to the earlier problem is that the consumer still allocates income toward the purchase of market goods, but now total income is in present value form, $Y = \sum \beta^t y_t$ where y_t is income in period t. A simple time separable model such as this can be used to extend the earlier concepts of value developed for a single period into a dynamic framework. I am going to assume that X_t is a composite good consisting of expenditures on the market goods in period t. Thus, expenditures on market goods and levels of nonmarket goods exist in each period that drive utility. The important feature of this model is that the individual efficiently allocates income between periods. Namely that the marginal benefit of spending on market goods in each period is equated in present value terms.

(30) $$\frac{\partial u(X_0, Q_0)}{\partial X} = \beta^t \frac{\partial u(X_t, Q_t)}{\partial X}$$

This condition must hold for all t under optimal income allocation. The consideration is what a marginal change in Q_t is worth in the current period. We know from the earlier static analysis that in period t, the marginal value for the change will be given by $p_t^v = \left(\partial u(X_t, Q_t)/\partial Q\right)/\left(\partial u(X_t, Q_t)/\partial X\right)$. By (30), the value today for the marginal change in the future will simply be given by $\beta^t p_t^v$.

Thus the margin value of Q in the dynamic model is simply the discounted value of the marginal value in the respective period.

For discrete changes, we would like the total amount of income today that the consumer is willing to give up for some change in the sequence of nonmarket goods, $\{Q_t\}$. Brackets are used because we must represent nonmarket goods' levels for T periods and T may be infinite. Assuming we are interested in a compensating measure of welfare, the logical extension from the marginal case is to use the present value discounted stream of compensating surplus in each period as our welfare measure. This generalization meets our needs provided that the allocation of income is unaffected by the sequence of nonmarket goods, $\{Q_t\}$. However, when income allocation is affected by this sequence, the proposed welfare measure, present value discounted compensating surplus in each period essentially values the changes in the sequence while imposing that the income allocation stay fixed. Thus for increases in nonmarket goods, the present value of the compensating surpluses will underestimate the desired welfare measure, and the present value of equivalent surpluses will overstate the amount. The reasoning is that for both cases, the ability to reallocate income is worth money. For the compensating measure, we would pay for this flexibility over the restricted case measured by the present value of the compensating surpluses from each period. Thus the divergence between the compensating measure with flexibility and our approximation. For equivalent surplus, the ability to reallocate income makes giving up the change in $\{Q_t\}$ not as bad. For decreases in $\{Q_t\}$, the opposite is true in both cases.

Practically speaking, the standard practice is to estimate the periodic benefits and then discount them. The choice of the discount rate is a sensitive issue that I will not address here.[20] Since we are estimating future benefits in today's dollars, the appropriate discount rate should not include an inflationary component.

4.1 Values in an Uncertain World

A great deal of uncertainty exists regarding our willingness to trade money for nonmarket goods. For example, the levels of nonmarket goods provided by a policy may be uncertain, prices of market goods that will occur once the policy is implemented may be uncertain, and the direct cost if the policy is enacted may be uncertain. Policies can affect the distributions of all of these random variables. The question then becomes one of how do we extend the welfare measures developed in the earlier section to cases of uncertainty?

To begin, I will exclusively consider uncertainty regarding the distribution of Q, assuming away time.[21] Q can accommodate things as different as the amount of open space that will actually be purchased by a bond initiative or the level of environmental risk associated with living or working in a given area. In relation to the earlier models, we now assume that individuals allocate income toward the purchase of market goods according to expected utility maximization.

$$\max_{X} E_Q[\ U(X, Q)\ ] \quad s.t. \quad p{\cdot}X \le y \tag{31}$$

Here, the allocation of income depends on the distribution of Q, which involves different possible levels instead of a particular level. The distribution of Q can be discrete or continuous. The maximized expected utility depends on the prices of the market goods, income, and the probability distribution of Q. Policies now act on the distribution associated with Q . Letting F denote the probability distribution of Q, maximized expected utility is then given by an indirect utility function, $v^E(P, y, F)$.[22] The concept that I focus on is option price. Option price is defined as the amount of income given that makes the individual indifferent between the status quo level of expected utility and the new expected utility under the changed distribution.

$$v^E(p, y - OP, F^1) = v^E(p, y, F^0) \tag{32}$$

In cases such as bond issues for the provision of open space, we typically pay some single, specified amount over time. The amount of open space that will actually be purchased is uncertain. In this case, option price is a very close analog to compensating surplus from before. In fact, contingent valuation surveys are generally measuring option price since some uncertainty almost always exists. Other important concepts involving environmental valuation and uncertainty are not covered here.[23]

4.2 Averting Expenditures

When facing environmental risks, individuals may independently undertake costly risk reduction. Examples include the purchase of bottled water and purchasing air bags for the car, to name a few. Since individuals spend money on providing a more favorable probability distribution of the nonmarket good, averting expenditures offer an avenue for inferring the value of collective policies that affect the distribution. The idea here is that the probability distribution can be favorably affected through individual inputs as well as collective inputs. Let E_I denote the individual's expenditure dedicated toward individual improvement of the distribution of Q, and let E_G denote the government's expenditure dedicated toward improving this distribution. Now the individual chooses both the level of market expenditures and the level of E_I subject to E_G. As in the previous section, F is the probability distribution of Q. At the optimal level of E_I, the indirect expected utility function becomes $v^E(P, y, F(E_I, E_G))$. A necessary condition for optimization is that the marginal benefit of more E_I equals the marginal utility of additional income.

(33) $$\frac{\partial v^E}{\partial F}\frac{\partial F}{\partial E_I} = \lambda$$

The marginal value of additional government expenditure dedicated toward improving the distribution of Q, denoted p_G^v, can be represented as the marginal utility of the expenditure function divided by the marginal utility of income.

(34) $$p_G^v = \frac{\partial v^E}{\partial F}\frac{\partial F}{\partial E_G}\frac{1}{\lambda}$$

From (33) and (34), we can solve for the marginal value of E_G. The way in which E_I enters the problem, the marginal value of E_G reduces to what is similar to the marginal rate of transformation for inputs.

(35) $$p_G^v = \frac{\frac{\partial v^E}{\partial F}\frac{\partial F}{\partial E_G}}{\frac{\partial v^E}{\partial F}\frac{\partial F}{\partial E_I}} = \frac{\frac{\partial F}{\partial E_G}}{\frac{\partial F}{\partial E_I}}$$

In this case, we only need to understand the relative production possibilities between private and public expenditures. This technique is conceptually similar to the household production framework. As with household production framework, if expenditures made toward improving the probability distribution also affect other aspects of utility, the marginal value expression is more complicated than (36).

5. PARTING THOUGHTS

All of the models above are based on the assumptions that individuals understand their preferences and make choices so as to maximize their welfare. Even under optimal conditions, inferring values for nonmarket goods is difficult. The nonmarket valuation practitioner needs to understand these concepts before heading into the field; to do otherwise could prove costly. There has never been a shortage of critics of welfare economics, either from inside or outside the profession. The underlying concepts need to be challenged, refined if possible, and even discarded if necessary. Nonmarket valuation researchers are on the cutting edge of these conceptual issues, a necessary trend that will undoubtedly continue.

NOTES

1 These topics alone could constitute an entire book. My treatment of each must be brief. For those launching a career in this area, I recommend Freeman (1993) and Hanley, Shogren, and White (1997).

2 The utility function is ordinal in the sense that many different functions could be used to equally represent a given preference ordering. For a complete discussion of preference orderings and their representations by utility functions, see Kreps (1990) or Varian (1996).

3 As discussed below, I can choose goods that have environmental quality attributes, *e.g.* air quality and noise. These goods are rationed in the sense that I cannot unilaterally improve ambient air quality or noise level at my current house. I can move to a new location where air quality is better, but I cannot determine the level of air quality at my current location.

4 It may be the case that I have to pay for Q^0. Rather than include this payment in the budget constraint, I simply consider income to already be adjusted by this amount. Because the levels of the nonmarket goods are not individually chosen, we need not include payments for nonmarket goods in the budget constraint.

5 To clarify notation, $p{\cdot}X = p_1{\cdot}x_1 + p_2{\cdot}x_2 + \ldots + p_n{\cdot}x_n$ where p_i is the price of market good *i*.

6 Interest over the difference in size has received considerable attention. For price changes, Willig (1976) provides an analysis. For quantity changes, see Randall and Stoll (1980) and Hanemann (1991). Hanemann (1999) provides a comprehensive, and technical review of these issues.

7 Roy's identity states that the derivative of the expenditure function with respect to price *i* is simply the Hicksian demand for good *i*. The fundamental theorem of calculus allows us to write the difference of two differentiable functions as the integral over the derivative of that function.

8 An example is the case of weak substitutability provided in Feenberg and Mills (1980).

9 Other approaches to infer the marginal value of a nonmarket good, such as Neill (1988), Larson (1992), and Flores (1996).

10 We must model preferences and production technology if we have a produced good that uses and nonmarket good *q* and the consumer values *q* outside of the production process.

11 Hedonism - pursuit of or devotion to pleasure.

12 The classic citations in this area are Griliches (1971), Rosen (1974), and Palmquist (1984).

13 Cicchetti and Wilde (1992) have argued that Krutilla's arguments, and hence passive use value, only apply to highly unique resources. However in footnote 5, Krutilla notes "Uniqueness need not be absolute for the following arguments to hold."

14 In discussing trends, Krutilla gives the example of the evolution from a family that car-camps to a new generation of back packers, canoe cruisers, and cross-country skiers.

15 The terms option value, preservation value, stewardship value, bequest value, inherent value, intrinsic value, vicarious consumption value, and intangible value have been used to describe passive use values. Carson *et al*. (1999) note these are motivations rather than distinct values.

16 See Portney (1994), Hanemann (1994), and Diamond and Hausman (1994).

17 The special case where $g(X, Q) = g(X)$ has been referred to as the hopeless case because the ordinary demands are independent of the levels of Q, leaving no hope for recovering the value of Q from demand data.

18 Dividing passive use value into bequest value, existence value, and the like will provide similarly inconclusive results. The decompositions will not be unique.

19 Maler, Gren, and Folke (1994) similarly define use values as those values that rely on observed market behavior for inference.

20 For examples, see Fisher and Krutilla (1975), Horowitz (1996), Porter (1982), and Schelling (1997).

21 Time is an important dimension and uncertainty transcends time. However, there is not enough space to cover time and uncertainty together.

22 In accordance with standard probability theory, *F* consists of a sample space of outcomes and a probability law for all subsets of the sample space that satisfies the properties of a probability measure.

23 Influential papers in this area include Graham (1981), Weisbrod (1964), Schmalensee (1972), and Arrow (1974). Freeman (1993) provides a fairly comprehensive overview.

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