

Chapter 2

Conceptual Framework for Nonmarket Valuation

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Abstract This chapter provides an overview of the theoretical foundations of nonmarket valuation. The chapter first develops a model of individual choice where private goods are freely chosen but environmental goods are rationed from the individual's perspective. The model is used to define compensating and equivalent welfare measures for changes in prices and environmental goods. These welfare measures form the basis of the environmental values researchers seek to measure through nonmarket valuation. The chapter discusses the travel cost model with and without weak complementarity, the household production model, the hedonic model, and the general concept of passive-use value. The individual choice model is extended to a dynamic framework and separately to choice under uncertainty. Finally the chapter develops welfare measures associated with averting expenditures and random utility models.

Keywords Public goods • Welfare economics • Compensating welfare measures • Equivalent welfare measures • Weak complementarity • Passive-use value • Uncertainty • Averting expenditures • Random utility model

Serious practice of nonmarket valuation requires a working knowledge of the underlying 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 described in this book.

To do so, this chapter develops a model of individual choice that explicitly recognizes the public good nature of many applications. While the emphasis is on public goods, the concepts in this chapter and the methods in this book have broader applicability to newly introduced market goods and goods that are not pure public goods. This model is used to derive the basic welfare measures that non-market valuation studies measure. Moving toward a more specific framework, the

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chapter examines how market behavior can be used to identify the basic welfare measures for nonmarket goods. It also provides a discussion of situations for which market demands are not sufficient to recover the basic welfare measures, cases of passive-use value, and visits to new recreation sites. That is followed by a discussion of intertemporal choice and nonmarket valuation, nonmarket valuation under uncertainty, use of averting expenditures to value nonmarket goods, and, finally, welfare measures for discrete-choice, random utility models.¹

2.1 Theoretical Model of Nonmarket Goods

The chapter begins with some illustrative examples. Air quality, water quality of 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 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 common feature that everyone experiences the same level of the good. Citizens at a given location experience the same level of local air quality; citizens of a state or province experience the same level of water quality in the state's lakes and streams; and everyone shares the level of preserved public lands. People can choose where to live or recreate, but environmental quality at specific locations is effectively rationed. Rationed, common-level goods serve as the point of departure for standard neoclassical price theory in developing the theoretical framework for nonmarket valuation.

The basic premise of neoclassical economic theory is that people have preferences over goods—in this 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 the bundles of goods forms the basis of choice. The most fundamental element of economic theory is the preference ordering, or more simply, the desires of the individual—not money. Money plays an important role because individuals have a limited supply of money to buy some, but not all, of the things they want. An individual may desire improved air or water quality or the preservation of an endangered species for any reason, including personal use, bequests to future generations, or simply for the existence of the resource. Economic theory is silent with regard to motivation. As Becker (1993, p. 386) offered, 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 preferences.

¹These topics alone could constitute an entire book, but the treatment of each must be brief. For those launching a career in this area, Freeman (1993) and Hanley et al. (1997) are recommended.

Preference ordering can be represented through a utility function defined over goods. For these purposes, $X = [x_1, x_2, \dots, x_n]$ denotes a list or vector of all of the levels for the n market goods the individual chooses. The k nonmarket goods are similarly listed as $Q = [q_1, q_2, \dots, q_k]$. 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, i.e., a limited budget. For market goods, individuals choose the amount of each good to buy based on preferences, the relative prices of the market goods $P = (p_1, p_2, \dots, p_n)$, 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 toward the purchase of market goods is subject to a rationed level of the nonmarket goods:

$$\max_X U(X, Q) \text{ s.t. } P \cdot X \leq y, Q = Q^0. \quad (2.1)$$

There are two constraints that people face in Eq. (2.1). First, the total expenditure on market goods cannot exceed income (budget constraint),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, there is 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 one plugs the set of optimal demands into the utility function, he or she obtains 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

²The 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 (1992).

³One can choose goods that have environmental quality attributes, e.g., air quality and noise. These goods are rationed in the sense that an individual cannot unilaterally improve ambient air quality or noise level at his or her current house. One can move to a new location where air quality is better but cannot determine the level of air quality at his or her current location.

⁴It may be the case that one has to pay for Q^0 . Rather than including this payment in the budget constraint, he or she can simply consider income to already be adjusted by this amount. Because the levels of the nonmarket goods are not individually chosen, there is no need to include payments for nonmarket goods in the budget constraint.

⁵To clarify notation, $p \cdot X = p_1x_1 + p_2x_2 + \dots + p_nx_n$, where p_i is the price of market good i .

interpreted as marginal value curves because consumption of goods occurs up to the point where marginal benefits equal marginal costs. For this reason, demand has social significance.

2.1.1 *Compensating and Equivalent Welfare Measures*

Policies or projects that provide nonmarket goods often involve costs. Values may be assigned 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, Colo. I care about this stream because I jog along its banks and enjoy the wildlife it supports, including the trout my daughters may catch when they are lucky. To pay for a cleanup of this creek, 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 that are standard fare in welfare economics can be used to assess the benefit of cleaning up Boulder Creek. The first is the amount of income I would give up after the policy has been implemented that would exactly return my utility to the status quo utility level before cleanup. This measure is the “compensating” welfare measure, which is referred to as C . Letting “0” superscripts denote the initial, status quo conditions and “1” superscripts denote the new conditions provided by the policy, C is generally defined using the indirect utility function as follows:

$$v(P^0, Q^0, y^0) = v(P^1, Q^1, y^1 - C). \quad (2.2)$$

The basic idea behind C is that if I give up C at the same time I experience the changes $(P^0, Q^0, y^0) \rightarrow (P^1, Q^1, y^1)$, then I am back to my original utility. My notation here reflects a general set of changes in prices, rationed nonmarket goods, and income. In many cases, including the example of water quality in Boulder Creek, only environmental quality is changing. C could be positive or negative, depending on how much prices increase and/or the size of any lump sum tax 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 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

$$v(P^0, Q^0, y^0 + E) = v(P^1, Q^1, y^1). \quad (2.3)$$

The two measures differ by the implied assignment of property rights. For the compensating measure, the initial utility level is recognized as the basis of comparison. For the equivalent measure, the subsequent level of utility is recognized 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 a new policy intended to improve Boulder Creek's water quality is being considered. In this case, the legal property right is the status quo; therefore, the analyst should use the compensating welfare measure. There are, however, instances when the equivalent welfare measure is conceptually correct. Returning to the water quality example, in the U.S., the Clean Water Act provides minimum water quality standards. If water quality declined below a standard and the project under consideration 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

2.1.2 Duality and the Expenditure Function

So far, the indirect utility function has been used to describe the basic welfare measures used in economic policy analysis. To more easily discuss and analyze specific changes, the analyst can equivalently use the expenditure function to develop welfare measures. The indirect utility function represents the highest level of utility obtainable when facing prices P , nonmarket goods Q , and income y .

Expenditure minimization is the flip side of utility maximization and is necessary for utility maximization. To illustrate this, suppose an individual makes market good purchases facing prices P and nonmarket goods Q and obtains a utility level of U^0 . Now suppose he or she is not minimizing expenditures, and U^0 could be obtained for less money through a different choice of market goods. If this were true, the person would not be maximizing utility because he or she could purchase the alternative, cheaper bundle that provides 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 microeconomics refers to as "duality." Instead of looking at maximizing utility subject to the budget constraint, the dual objective of minimizing expenditures—subject to obtaining a given level of utility—can be considered. The expenditure minimization problem is stated as follows:

$$\min_x P \cdot X \text{ s.t. } U(X, Q) \geq U^0, Q = Q^0. \quad (2.4)$$

The solution to this problem is the set of compensated or Hicksian demands that are a function of prices, nonmarket goods levels, and level of utility,

⁶Interest over the difference in size between C and E has received considerable attention. For price changes, Willig (1976) provided an analysis. For quantity changes, see Randall and Stoll (1980) and Hanemann (1991). Hanemann (1999) provided a comprehensive and technical review of these issues. From the perspective of measurement, there is a general consensus that it is more difficult to measure E , particularly in stated preference analysis.

$X^* = X^h(P, Q, U)$. The dual relationship between the ordinary demands and the Hicksian demands is that they intersect at an optimal allocation $X(P, Q, y) = X^h(P, Q, U)$ when $U = v(P, Q, y)$ in the expenditure minimization problem and $y = P \cdot X^h(P, Q, y)$ in the utility maximization problem.

As the term “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, $e(P, Q, y) = P \cdot X^h(P, Q, U)$, 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 one to decompose a policy that changes multiple goods or prices into a sequence of changes that will be shown to provide powerful insight into our welfare measures.

This chapter has so far introduced the broad concepts of compensating and equivalent welfare measures. Hicks (Hicks 1943) developed the compensating and equivalent measures distinctly for price and quantity changes and named them the price compensating/equivalent variation for changes in prices and the quantity compensating/equivalent variation for quantity changes, respectively. 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 compensating/equivalent variations and surpluses, income changes should be discussed. Income changes can also occur as a result of policies, so changes in income are discussed first. For example, regulating the actions of polluting firms may decrease the demand for labor and result in lower incomes for workers.

2.1.3 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. The two measures are defined by the fundamental identities as follows:

$$v(P^0, Q^0, y^0) = v(P^1, Q^1, y^1 - C) \quad (2.5a)$$

$$v(P^0, Q^0, y^0 + E) = v(P^1, Q^1, y^1) \quad (2.5b)$$

Also, C and E can be represented using the expenditure function:

$$C = e(P^1, Q^1, U^1) - e(P^1, Q^1, U^0), \quad (2.6a)$$

$$E = e(P^0, Q^0, U^1) - e(P^0, Q^0, U^0) \quad (2.6b)$$

To determine how to handle income changes, C and E need to be rewritten 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, C and E can be rewritten as

$$C = e(P^0, Q^0, U^0) - e(P^1, Q^1, U^0) + (y^1 - y^0). \quad (2.7a)$$

$$E = e(P^0, Q^0, U^1) - e(P^1, Q^1, U^1) + (y^1 - y^0) \quad (2.7b)$$

The new form shows that for C , one values the changes in prices and nonmarket goods at the initial utility level and then considers the income change. For E , one values the changes in prices and nonmarket goods at the post-change utility level and then considers income change. The generalized compensated measure is subtracted from income under the subsequent conditions (Eq. 2.2), while the generalized equivalent measure is added to income under the initial conditions (Eq. 2.3), regardless of the direction of changes in P or Q . How the changes in prices and nonmarket goods are valued is the next question.

2.1.4 Variation Welfare Measures for a Change in Price i

Suppose the analyst is considering a policy that only provides a price increase for good i . Hicks (1943) referred to the compensating welfare measure for a price change as “compensating variation” (CV) and to the equivalent welfare measure as “equivalent variation” (EV). Because a price decrease makes the consumer better off, both measures are positive. P_{-i} refers to the price vector left after removing p_i :

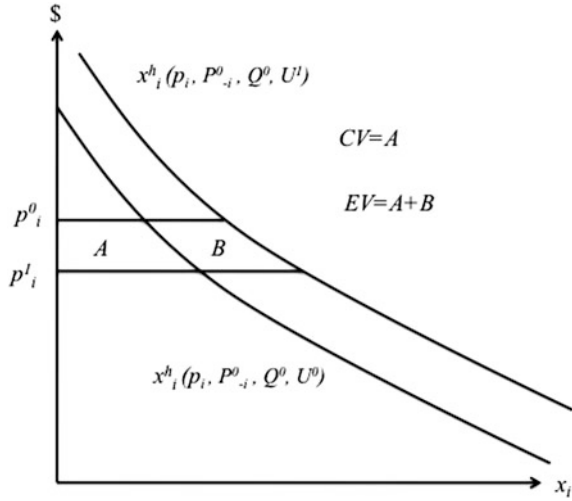
$$CV = e(p_i^0, P_{-i}^0, Q^0, U^0) - e(p_i^1, P_{-i}^0, Q^0, U^0); \quad (2.8)$$

$$EV = e(p_i^0, P_{-i}^0, Q^0, U^1) - e(p_i^1, P_{-i}^0, Q^0, U^1). \quad (2.9)$$

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:

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

Fig. 2.1 Compensating and equivalent variations for a decrease in p_i



$$\begin{aligned}
 CV &= e(p_i^0, P_{-i}^0, Q^0, U^0) - e(p_i^1, P_{-i}^0, Q^0, U^0) \\
 &= \int_{p_i^1}^{p_i^0} x_i^h(s, P_{-i}^0, U^0) ds;
 \end{aligned} \tag{2.10}$$

$$\begin{aligned}
 EV &= e(p_i^0, P_{-i}^0, Q^0, U^1) - e(p_i^1, P_{-i}^0, Q^0, U^1). \\
 &= \int_{p_i^1}^{p_i^0} x_i^h(s, P_{-i}^0, U^1) ds.
 \end{aligned} \tag{2.11}$$

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 2.1 depicts these two measures for the price change.

A few issues regarding the welfare analysis of price changes deserve mention. First, only a single price change has been presented. 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). An example of how to do this is provided in the discussion of weak in Sect. 2.2.2. 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) had 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 approach 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, the analyst also needs 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, an individual takes away a negative amount, i.e., gives money, because the new price level makes him or her worse off. Similarly, one would have to give up money at the old price in order to equate the status quo utility with the utility at the new price, which is equivalent to saying a negative equivalent variation exists.

2.1.5 Welfare Measures for a Change in Nonmarket Goods

Now suppose one is considering an increase in the amount of the nonmarket good q_j . This change could represent acres of open space preserved, something that most would consider a quantity change, or the level of dissolved oxygen in a stream, a quality change that can be measured. Recall that the 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:

$$CS = e(P^0, Q^0, U^0) - e(P^0, Q^1, U^0); \quad (2.12)$$

$$ES = e(P^0, Q^0, U^1) - e(P^0, Q^1, U^1). \quad (2.13)$$

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 q_j is simply the negative of the inverse Hicksian demand curve for nonmarket good q_j . This derivative equals the negative of the virtual price—the shadow value—of nonmarket good q_j . Again applying the fundamental theorem of calculus, the analyst can rewrite the surplus measures in terms of this shadow value. 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.

$$\begin{aligned} CS &= e(P^0, q_j^0, Q_{-j}^0, U^0) - e(P^0, q_j^1, Q_{-j}^0, U^0) \\ &= \int_{q_j^0}^{q_j^1} p_i^v(P^0, s, Q_{-j}^0, U^0) ds; \end{aligned} \quad (2.14)$$

$$\begin{aligned} ES &= e(P^0, q_j^0, Q_{-j}^0, U^1) - e(P^0, q_j^1, Q_{-j}^0, U^1) \\ &= \int_{q_j^0}^{q_j^1} p_i^v(P^0, s, Q_{-j}^0, U^1) ds. \end{aligned} \quad (2.15)$$

Fig. 2.2 Compensating and equivalent surpluses for an increase in q_j

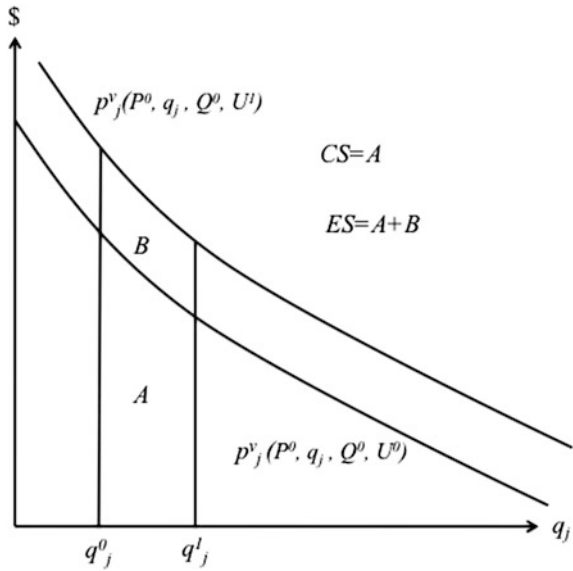


Figure 2.2 graphs the compensating and equivalent surpluses for this increase in nonmarket good q_j . The graph looks similar to Fig. 2.1 except that the change is occurring in the quantity space as opposed to the price space. For normal nonmarket goods—goods where the quantity desired increases with income—the equivalent measure will exceed the compensating measure for increases in the nonmarket good. For decreases in the nonmarket good, the opposite is true.

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 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 and equivalent variations and surpluses.

Table 1 Willingness to pay and willingness to accept

Welfare measure	Price increase	Price decrease
	WTP to avoid	WTA to forgo
Equivalent variation—Implied property right in the change		
Compensating variation—Implied property right in the status quo	WTA to accept	WTP to obtain

Source Freeman [1993, p. 58)

2.1.6 Compensating and Equivalent Variations and Willingness to Pay and Willingness

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 2.1 for a price change.

As the table suggests, one needs to be explicit about what he or she is paying for when using WTP, and one needs to be explicit about what he or she is being compensated for when using WTA. In cases where utility changes are unambiguously positive or negative, the WTP/WTA terminology works well. However, when combinations of desirable and undesirable changes exist, 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 to forgo the policy. The situation could result in mixed losses and gains, leading one to measure WTA for losers and WTP for gainers, using the WTP/WTA terminology. Using equivalent or compensating welfare measures, one measure is used for losers and gainers. Hanemann (1991, 1999) provided theoretical and empirical evidence that the difference between compensating and equivalent measures can be quite dramatic. WTP for the increase in a unique nonmarket good that has virtually no substitutes can be many orders of magnitude smaller than WTA compensation to give up the increase.

These concepts refer to gains and losses at the individual level. There are different approaches to aggregating information from individuals to make collective choices. The Kaldor–Hicks criterion is the most widely used approach to aggregating compensating or equivalent welfare measures. A proposed change passes the Kaldor test if the sum of the compensating measures is greater than zero; the proposed change passes the Hicks test if the sum of equivalent measures is greater than zero.

As noted by Freeman (1993), the choice of test depends on the decision context. The Kaldor–Hicks criterion implies that projects passing the selected test satisfy the requirement that the gains of winners are more than sufficient to compensate the losers, leading to the potential that the change could occur with redistribution of income where some gain and none lose. It is important to recognize that compensation need not occur.

2.2 Implicit Markets for Environmental Goods

By definition, individuals do not explicitly purchase nonmarket goods. They do, however, purchase other goods for which demands are related to nonmarket goods. For example, one's choice of where to recreate may depend on the environmental quality of the sites under consideration. Furthermore, environmental quality can influence one's choice of which community to live in or which house to buy once he or she has decided on a community. These market links to nonmarket goods make 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 Chaps. 6 through 8. Section 2.2 reviews some of the concepts related to inferring environmental values from market purchases.

2.2.1 Price Changes and Environmental Values

This section develops a framework that relates changes in nonmarket goods to price changes in market goods. This is done in order to introduce the weak complementarity condition, a condition that, if satisfied, allows changes in nonmarket goods to be valued through changes in consumer surplus of affected market goods. Suppose one is increasing the first nonmarket good q_1 , wishes to measure the monetary value for this change, and determines 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 :

$$CS = e(P^0, q_1^0, Q_{-1}^0, U^0) - e(P^0, q_1^1, Q_{-1}^0, U^0). \quad (2.16)$$

The next step is the introduction of an arbitrary price change along with this quantity change by adding and subtracting two different terms. The size of the compensating surplus has not changed:

$$\begin{aligned} CS = & e(P^1, q_1^1, Q_{-1}^0, U^0) - e(P^0, q_1^1, Q_{-1}^0, U^0) \\ & - [e(P^1, q_1^0, Q_{-1}^0, U^0) - e(P^0, q_1^0, Q_{-1}^0, U^0)] \\ & + e(P^1, q_1^0, Q_{-1}^0, U_0) - e(P^1, q_1^1, Q_{-1}^0, U^0). \end{aligned} \quad (2.17)$$

The second and fourth terms are the original terms in (2.16) 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”—which is discussed next—is satisfied, this arrangement is useful and forms the basis for the travel cost method presented in Chap. 6.

2.2.2 Weak Complementarity

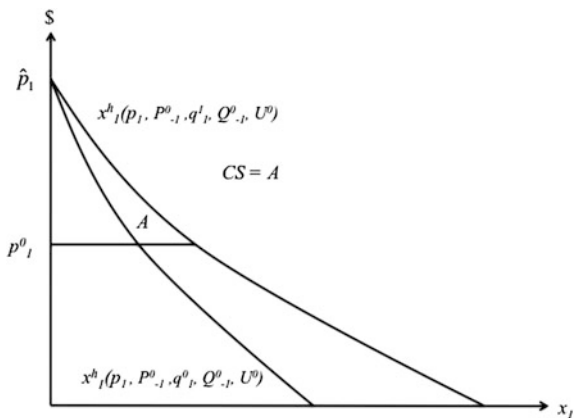
Suppose the compensated demand for Market Good 1 (x_1) depends on the level of q_1 in a marginally positive way; that is, the demand curve shifts out as q_1 increases. Further suppose that if consumption of this market good is zero, the marginal value for the change in q_1 is zero. Maler (1974) referred to this situation as weak complementarity. Now, turning back to the way that compensating surplus was rewritten in Eq. (2.17), suppose 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 :

$$\begin{aligned}
 CS = & e(\hat{p}_1, P_{-1}^0, q_1^1, Q_{-1}^0, U^0) - e(p_1^0, P_{-1}^0, q_1^1, Q_{-1}^0, U^0) \\
 & - [e(\hat{p}_1, P_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(p_1^0, P_{-1}^0, q_1^0, Q_{-1}^0, U^0)] \\
 & + e(\hat{p}_1, P_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(\hat{p}_1, P_{-1}^0, q_1^1, Q_{-1}^0, U^0).
 \end{aligned} \tag{2.18}$$

By definition, demand for the weakly complementary good is zero at \hat{p}_1 and so the last line of Eq. (2.18) equals zero. Now the compensating surplus is simply the change in total consumer surplus for the weakly complementary good:

$$\begin{aligned}
 CS = & e(\hat{p}_1, P_{-1}^0, q_1^1, Q_{-1}^0, U^0) - e(p_1^0, P_{-1}^0, q_1^1, P_{-1}^0, U^0) \\
 & - [e(\hat{p}_1, P_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(p_1^0, P_{-1}^0, q_1^0, Q_{-1}^0, U^0)] \\
 & + \int_{\hat{p}_1^0}^{\hat{p}_1} x_1^h(s, P_{-1}^0, q_1^1, Q_{-1}^0, U^0) ds - \int_{p_1^0}^{\hat{p}_1} x_1^h(s, P_{-1}^0, q_1^0, Q_{-1}^0, U^0) ds.
 \end{aligned} \tag{2.19}$$

Fig. 2.3 Weak complementarity of market good x_1 and CS for a change in nonmarket good q_1



Weak complementarity is convenient because valuing the change in the non-market good is possible by valuing the change in consumer surplus from the weakly complementary good. Figure 2.3 graphically depicts compensating surplus for this weakly complementary good.

Consumption of several goods might need to be zero in order for the marginal value of q_1 to equal zero. An example is improving 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 presented so far. The difference is the way the sequence of price changes is dealt with. The final line in the analog to (2.18) would still equal zero. However, there are multiple prices to consider. Consider a simple example of how the prices of two goods would need to be adjusted. Suppose that if demand for Market Good 1 and 2 is zero, then the marginal value for the change in q_1 equals zero. Compensating surplus is then given as follows. Similar to the earlier notation, $P^0_{-1,-2}$ is the price vector formed by removing the first and second elements of P^0 :

$$\begin{aligned}
 CS = & \int_{\hat{P}_1^0}^{\hat{P}_1} x_1^h(s, P^0_{-1}, q_1^1, Q^0_{-1}, U^0) ds \\
 & - \int_{\hat{P}_1^0}^{\hat{P}_1} x_1^h(s, P^0_{-1}, q_1^0, Q^0_{-1}, U^0) ds \\
 & + \int_{\hat{P}_2^0}^{\hat{P}_2} x_2^h(\hat{P}_1, s, P^0_{-1,-2}, q_1^1, Q^0_{-1}, U^0) ds \\
 & - \int_{P_2^0}^{\hat{P}_2} x_2^h(\hat{P}_1, s, P^0_{-1,-2}, q_1^0, Q^0_{-1}, U^0) ds.
 \end{aligned} \tag{2.20}$$

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 there were a third good, the change in consumer surplus for the third good would be conditioned on the choke prices of Goods 1 and 2. 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 the other prices are conditioned correctly (Braeutigam and Noll 1984).

Before moving on to inference for marginal values, two issues related to weak complementary goods should be mentioned. First, the analyst does not need to rule

out a market price other than the choke price for which he or she obtains the condition that the marginal value of the market good is zero.⁸ Any price that results in this condition allows the compensating surplus to be derived from the compensated market demands. The techniques discussed in this section will handle any such price. The second issue is the impact of incorrectly assuming weak complementarity. The last term that vanishes under weak complementarity will be positive if one incorrectly assumes weak complementarity for increases in the nonmarket good, and negative for decreases. The value inferred from the good that is incorrectly assumed to be weakly complementary will bound compensating surplus either below, for increases in the nonmarket good, or above for decreases.

2.2.3 Household Production Framework

A slightly different approach to that presented above is the household production framework. The household production framework is the basis for the defensive behavior approach to nonmarket valuation described in Chap. 8. Suppose the analyst is interested in determining the marginal value of a single nonmarket good q_j . The household production framework posits a production relationship between the consumption of goods x_p and q_j . The good produced in this process is a final product that the consumer values. Partition the vector X into $[X_{-p}, x_p]$, where x_p is a good produced by the individual according to the production process $x_p = f(I, q_j)$. I is a marketed production input, X_{-p} is the vector of market goods consumed, p_{-p} is a vector of prices for the market goods, and p_I is the price for the marketed production input. Assuming that q_j enters the choice problem only through production of x_p , the utility maximization problem is

$$\max_{X_{-p}, I} U(X_{-p}, x_p) \text{ s.t. } p_{-p} \cdot X_{-p} + p_I \cdot I \leq y, q_j = q_j^0, x_p = f(I, q_j). \quad (2.21)$$

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 $p_{q_j}^v$, the object of interest. With knowledge of the marginal value, one can approximate the value for a discrete change by integrating over the marginal value similar to Eqs. (2.10) and (2.11):

$$\frac{\partial U}{\partial x_p} \cdot \frac{\partial f}{\partial I} = \lambda \cdot p_I \quad \frac{\partial U}{\partial x_p} \cdot \frac{\partial f}{\partial q_j} = p_{q_j}^v \lambda. \quad (2.22)$$

From these two equations, one can solve for the marginal value of q_j :

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

$$p_q^v = p_l \cdot \frac{\left(\frac{\partial f}{\partial q}\right)}{\left(\frac{\partial f}{\partial l}\right)}. \quad (2.23)$$

Thus, the marginal value of q_j can be derived from the price of the marketed production input and the marginal rate of transformation between the input and q_j . The desirable property of this technique is that there is no need to model preferences. Of course, the analyst still has to model the production process. Moving away from a single input and a single produced good quickly complicates the model. Preferences need to be modeled because marginal utilities come into play. Therefore, the analyst needs to model the production process *and* consumer preferences, which creates an additional layer to the basic framework that has been presented.

2.2.4 *The Hedonic Concept*

Some goods that are consumed can be viewed as bundles of attributes. For example, houses have distinguishing attributes such as square footage, number of bedrooms, location, and environmental attributes. Public land is an example of a publicly owned environmental good that provides open space that is accessible to all. Being close to open space is, for some, a valuable attribute. Holding all other characteristics of houses constant, houses closer to open space have higher sale prices. 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, there is an implicit market in this attribute because the home price varies by distance to open space. This concept underlies the hedonic nonmarket valuation technique described in Chap. 7. Other examples of attributes in the housing market are air quality, busy streets, and power lines. Environmental risk is an attribute of jobs, which are objects of choice that implicitly offer people 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 distance to open space or job risk, which are not explicitly traded in markets.⁹

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, the consumer does not individually purchase open space; thus, the quantity of Q is fixed. He or she can, however, purchase a home closer to the open

⁹The classic citations in this area are Griliches (1971), Rosen (1974), and Palmquist (1984).

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 a large city cannot unilaterally affect this gradient, but he or she can choose where to live along the gradient. The resident can choose a house based on where it falls along the air quality gradient. He or she can care a great deal about the gradient itself in ways other than the choice of housing. For example, the resident can live near the beach, which has relatively good air quality, and yet be subjected to really poor air quality at work downtown. Similarly, the resident can locate near the North Boulder open space and yet care a great deal about whether Boulder County purchases another tract of land in South Boulder. The point here is that Q can enter one's utility for life at home and also enter separately in the utility function for other purposes.

The basic approach to the hedonic method is that the house is really a bundle of attributes. Because other people also care about these attributes, they are scarce and valuable. Although the consumer pays a bundled price for the house, the price buys the package of 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 partitions 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:

$$\begin{aligned} & \max_{X, Q_2} U(X_1, X_2, Q_1, Q_2) \\ \text{s.t. } & p_1 \cdot X_1 + p_h(X_2, Q_2) \leq y, \quad Q_1 = Q_1^0. \end{aligned} \quad (2.24)$$

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 marginal rates of substitution for elements in Q_2 and X_2 are equal to the relative marginal costs, i.e., prices:

$$\begin{aligned} \frac{\left(\frac{\partial U}{\partial q_j}\right)}{\left(\frac{\partial U}{\partial x_j}\right)} &= \frac{\left(\frac{\partial p_h}{\partial q_j}\right)}{\left(\frac{\partial p_h}{\partial x_j}\right)} & q_j \in Q_2, \quad x_j \in X_2 \\ \frac{\left(\frac{\partial U}{\partial q_j}\right)}{\left(\frac{\partial U}{\partial x_j}\right)} &= \frac{\left(\frac{\partial p_h}{\partial q_j}\right)}{p_i} & q_j \in Q_2, \quad x_j \in X_2. \end{aligned} \quad (2.25)$$

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 are typically 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 provides information on the marginal values of Q_2 . Additional

structure that is discussed in Chap. 7 facilitates estimation of the demand functions that can then be used to value nonmarginal changes.

2.2.5 *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 or qualities of the nonmarket goods accompanying the observed transactions to be able to statistically identify these relationships. The concepts outlined in the earlier sections form the basis for revealed preference nonmarket valuation techniques described in Chaps. 6, “Travel Cost”; 7, “Hedonics”; and 8, “Defensive Behavior and Damage Cost Methods.”

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. A lack of identifiable link for some people does not mean they do not value the nonmarket good. Value for these individuals for whom there is no identifiable or estimable link is referred to as nonuse 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 the Interior*, which gave legal standing to the concept. Drawing on earlier work from Carson et al. (1999), a brief overview of how this concept evolved follows.

In a highly influential article, Krutilla (1967) suggested that revealed preference techniques might not accurately measure societal values. The strength of his argument came through examples; the paper provides no theory. Using unique resources such as the Grand Canyon, and considering irreversible changes, Krutilla (1967) made a number of important points.¹⁰

First, demand for the environment has dynamic characteristics that imply value for potential use, though not current use, and trends for future users need to be explicitly recognized in order to adequately preserve natural areas.¹¹

Second, some individuals may value the environment for its mere existence. Krutilla (1967, footnote 7, p. 779) 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

¹⁰Cicchetti and Wilde (1992) had contended that Krutilla’s (1967) arguments, and hence passive-use value, only apply to highly unique resources. However, Krutilla (Footnote 5, p. 778) noted that “Uniqueness need not be absolute for the following arguments to hold.”

¹¹In discussing trends, Krutilla (1967) gave the example of the evolution from a family that car camps to a new generation of backpackers, canoe cruisers, and cross-country skiers.

species or a disfigurement of a scenic area causes acute distress and a sense of genuine relative impoverishment.”

Third, the bequest of natural areas to future generations may be a motive for current nonusers to value preservation, particularly because given the dynamic characteristics mentioned previously, 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 (1967) and to measure the associated economic value.¹²

Measuring passive-use values and using them in policy analysis—particularly natural resource damage assessments—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 preferences from revealed actions in markets. However, stated preference methods such as contingent valuation (Chap. 4) and choice experiments (Chap. 5) are the only viable alternatives for measuring passive-use values. These stated preference methods draw inference from carefully designed scenarios of trade-offs that people are asked to evaluate in survey settings. From the trade-off responses, we learn about the preferences of individuals who hold passive-use values.

Some economists are skeptical about passive-use values in economic analysis, and the skepticism occurs on two levels. The first level involves the idea of whether or not passive-use values even exist. The second level involves the measurement of passive-use values because of the need to use stated preference techniques. To completely dismiss passive-use values is an extreme position and does not hold up to scrutiny because nonusers of areas like the Arctic Wildlife Refuge or the Amazon rain forest frequently lobby decision-makers to preserve these areas and spend money and other resources in the process. The latter concern is based on empirical observations that have been published in the literature.¹³

The remainder of this section will discuss how passive-use values have been viewed conceptually. While the 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 to 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 in Eq. (2.18). McConnell (1983) and Freeman (1993) defined passive-use value as this last term:

¹²The 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) noted that these are motivations rather than distinct values.

¹³See Carson (2012), Portney (1994), Hanemann (1994), and Diamond and Hausman (1994).

$$\begin{aligned}
CS = & e(\hat{p}_1, p_{-1}^0, q_1^1, Q_{-1}^0, U^0) - e(p_1^0, p_{-1}^0, q_1^1, Q_{-1}^0, U^0) \\
& - [e(\hat{p}_1, p_{-1}^0, q_1^0, Q_{-1}^0, U^0) - e(p_1^0, p_{-1}^0, q_1^0, Q_{-1}^0, U^0)] \\
& + PUV.
\end{aligned} \tag{2.26}$$

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 (2.26), and end up with a measure of passive-use value. Because one could do this for each good that is not a necessary good or any combination of goods in this category, multiple measures of passive-use value could be derived.

Another conceptual definition was suggested by Hanemann (1995) with 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.¹⁴ Hanemann (1995) defined passive-use value and use value according to the following two identities:

$$T[g(X(P, Q^0, y - PUV), Q^0), Q^1] = T[g(X(P, Q^0, y), Q^0), Q^0]; \text{ and} \tag{2.27}$$

$$T[g(X(P, Q^1, y - PUV - UV), Q^1), Q^1] = T[g(X(P, Q^0, y), Q^0), Q^0]. \tag{2.28}$$

The definitions implied by (2.26) and by (2.27) together with (2.28) decompose compensating surplus into two parts for which the sum of the parts equals the whole. Intuitively, Hanemann's (1995) definition works in reverse of the decomposition in (2.26). Because the same preferences can be defined differently, a passive-use value is a somewhat tenuous theoretical concept.¹⁵ Furthermore, neither definition is easy to implement because the first decomposition requires one to choose the market goods for which demand is choked. Using separate measurement, it is difficult if not impossible to elicit either of these concepts from 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" (p. 100).¹⁶ 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 (1995) definition. Analysts typically want to measure compensating or equivalent surplus,

¹⁴The 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.

¹⁵Dividing passive-use value into bequest value, existence value, and the like will provide similarly inconclusive results. The decompositions will not be unique.

¹⁶Maler et al. (1994) similarly defined use values as those values that rely on observed market behavior for inference.

also referred to as total value in this literature, but are less concerned with separate estimates of individual use and passive-use elements of the total value. The important social issue is the need to incorporate the values of all those who value the nonmarket good. To do so requires analysts, at times, to turn to stated preference techniques if they believe that passive-use values are likely to be decisive. Similarly, sometimes the use-value component alone can sufficiently inform decisions and allow analysts to rely on revealed behavior that some view as more credible. It is important to recognize that separating out use and passive-use values at the individual level is quite difficult and sometimes impractical because preferences along these two dimensions frequently interact.

2.3 Nonmarket Values in a Dynamic Environment

Most models of intertemporal choice in economics 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, $\gamma = 1/(1+r)$:

$$U = \sum_t^T \gamma^t u(X_t, Q_t). \quad (2.29)$$

Utility in each period depends on market goods X_t and nonmarket goods 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, $Y = \sum \gamma^t y_t$, 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. 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 (Q_t) exist in each period. The important feature of this model is that the individual efficiently allocates income between periods. That is to say, the marginal benefit of spending on market goods in each period is equated in present value terms:

$$\frac{\partial u(X_0, Q_0)}{\partial X} = \gamma^t \frac{\partial u(X_t, Q_t)}{\partial X}. \quad (2.30)$$

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. The marginal value for the change will be given by $p_t^v = (\partial u(X_t, Q_t)/\partial Q)/(\partial u(X_t, Q_t)/\partial X)$. By (2.30), the value today for the marginal change in the future will simply be given by $\gamma^t p_t^v$. 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, the analyst 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 the levels of nonmarket goods for T periods must be monitored, and T may be infinite. Assuming one is 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 the welfare measure. This generalization meets the 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, the present value discounted compensating surplus in each period, essentially values the changes in the sequence while imposing that the income allocation across periods is 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, one would pay for this flexibility over the restricted case measured by the present value of the compensating surpluses from each period. 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 will not be addressed here.¹⁷ Because the estimation is of future benefits in today's dollars, the appropriate discount rate should not include an inflationary component.

2.3.1 *Values in an Uncertain World*

A great amount 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 these random variables. The question then becomes one of how to extend the welfare measures developed in the previous section to cases of uncertainty.

Exclusively consider uncertainty regarding the distribution of Q , assuming away time.¹⁸ Q can accommodate things as different as the total amount of open space that will 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,

¹⁷For examples, see Fisher and Krutilla (1975), Horowitz (1996), Porter (1982), and Schelling (1997).

¹⁸Time is an important dimension, and uncertainty transcends time. However, there is not enough space to cover time and uncertainty together.

one now assumes that individuals allocate income toward the purchase of market goods according to expected utility maximization:

$$\max E_Q[U(X, Q)] \quad s.t. \quad P \cdot X \leq y. \quad (2.31)$$

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 . Values that influence policy choices are now dependent 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, $v^E(P, y, F)$.¹⁹ The central concept is option price. Option price is defined as the amount of money, a reduction in income in this example, that makes the individual indifferent between the status quo level of expected utility and the new expected utility under the changed distribution:

$$v^E(P, y - OP, F^1) = v^E(P, y, F^0). \quad (2.32)$$

Here, OP is the measure of compensating surplus under uncertainty. In cases such as bond issues for the provision of open space, residents 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 the open space example in Sect. 2.1.5. In fact, contingent valuation surveys generally measure option price because some uncertainty almost always exists. Other important concepts involving environmental valuation and uncertainty are not covered here.²⁰

2.3.2 Averting Expenditures

This section develops the broad conceptual framework for using averting expenditures as a means to value nonmarket goods—a topic that is taken up in detail in Chap. 8. When facing environmental risks, individuals may independently undertake costly risk reductions. Examples include the purchase of bottled water and purchasing air bags for the car, to name a few. Because individuals spend money to provide a more favorable probability distribution of the nonmarket good, averting expenditures offers an avenue for inferring the value of collective policies that affect the distribution. The idea here is that the probability distribution can be favorably

¹⁹In 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.

²⁰Influential papers in this area include Graham (1981), Weisbrod (1964), Schmalensee (1972), and Arrow and Fisher (1974). Freeman (1993) provided a fairly comprehensive overview.

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:

$$\frac{\partial v^E}{\partial F} \frac{\partial F}{\partial E_I} = \lambda. \quad (2.33)$$

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:

$$p_G^v = \frac{\partial v^E}{\partial F} \frac{\partial F}{\partial E_I} \frac{1}{\lambda}. \quad (2.34)$$

From (2.33) and (2.34), one 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:

$$p_G^v = \frac{\frac{\partial v^E}{\partial F} \frac{\partial F}{\partial E_G}}{\frac{\partial v^E}{\partial F} \frac{\partial F}{\partial E_I}} = \frac{\frac{\partial F}{\partial E_G}}{\frac{\partial F}{\partial E_I}} \quad (2.35)$$

In this case, one only needs to understand the relative production possibilities between private and public expenditures. This technique is conceptually similar to the household production framework. As with the 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 (2.35).

2.3.3 *Welfare in Discrete-Choice Random Utility Models*

Chapters 4, 5, 6, and 8 present discrete-choice random utility models that can be applied either in stated preference or revealed preference settings. Discrete-choice random utility models seek to describe choices over distinct alternatives that frequently vary by common attributes. For example, sport fishermen choose among competing fishing sites that are distinguished by distance from home as well as catch rates. Or choice experimental subjects may choose among alternative policies

that are distinguished by policy attributes such as acres of wilderness areas preserved, the number of species affected, and differences in household taxes.

The basic idea behind these models is that people receive utility from a given alternative that depends on a set of observable characteristics and other characteristics that are not observed by the researcher. The indirect utility of alternative j , conditional on having made that choice, is a function of a vector of observable characteristics Q_j , an unobservable random component ε_j , income y , and cost of that alternative p_j : $v_j = v(p_j, Q_j, \varepsilon_j, y)$. Specification of the functional form of the conditional indirect utility function and assumptions made regarding the probability distribution of the unobservable random component facilitate modeling the probability of choosing available alternatives that, in turn, provides estimates of conditional indirect utility function parameters. With regard to welfare analysis, the concepts are identical in spirit to those discussed above, though some consideration must be given to the unobservable random component associated with each alternative.

In the recreational demand setting, one could consider a change in the characteristics of, say, Site 1. The analysis starts with an initial set of vectors of observable characteristics for all J sites, $\{Q_1^0, Q_2^0, \dots, Q_J^0\}$. The policy being considered changes the characteristics of one site, Site 1 here, $\{Q_1^1, Q_2^0, \dots, Q_J^0\}$. With regard to welfare measures, of interest are the amount of income adjustment that would make an individual indifference between the initial set of characteristics and the new set of characteristics provided by the policy with the appropriate income adjustments, e.g., subtracting C along with the policy or adding E while forgoing the policy.

This framework allows the estimation of marginal values but is not designed to reveal specific site or alternative choices with changed conditions. That is, the random component in conditional indirect utility does not allow us to say with certainty which site will be chosen on the next trip with either the initial set of vectors or the new vector. Consider the optimal choice that the angler makes presented in (2.36). With regard to notation, $\{p\}$, $\{Q\}$, $\{\varepsilon\}$ are, respectively, the set of prices for each site, the set of observable attributes for each site, and the set of unobservable utility components for each site that is unknown to the researcher:

$$v^*(\{p\}, \{Q\}, \{\varepsilon\}, y) = \max_{j \in J} v(p_j, Q_j, \varepsilon_j, y). \quad (2.36)$$

In Sect. 2.3.1 on values in an uncertain world, individuals face uncertainty over Q . In this model, it is the researcher who faces uncertainty over the random utility components. In order to derive welfare measures, he or she considers the expected maximum utility as the value function, and the compensating and equivalent measures are as follows. Here, expectation is with regard to the unobservable error components, and the income adjustments are the same regardless of the site that is actually chosen:

$$E_{\varepsilon}[v^*(\{p\}, \{Q^0\}, \{\varepsilon\}, y)] = E_{\varepsilon}[v^*(\{p\}, \{Q^1\}, \{\varepsilon\}, y - C)]; \quad (2.37)$$

$$E_{\varepsilon}[v^*(\{p\}, \{Q^0\}, \{\varepsilon\}, y + E)] = E_{\varepsilon}[v^*(\{p\}, \{Q^1\}, \{\varepsilon\}, y)]. \quad (2.38)$$

The difficulty in analytically deriving these measures depends on the form of conditional indirect utility, the assumed distribution of the unobservable error components, and the number of choices available to agents.²¹ In some cases—such as binary choice questions in contingent valuation—solutions to these equations are straightforward, while in other cases, solutions are analytically intractable. It is important to recognize that in all cases, the basic principles are consistent with measures presented in Sect. 2.2.

2.4 Parting Thoughts

All of the models presented in this chapter 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 and requires thoughtful analysis. The nonmarket valuation practitioner needs to understand these concepts before heading into the field; to do otherwise could prove costly. Estimating credible welfare measures requires careful attention to the basic theoretical concepts so that value estimates meaningfully and clearly support decision-making. There has never been a shortage of critics of welfare economics—from inside or outside the profession. Nonmarket valuation researchers are on the cutting edge of these conceptual issues, a necessary trend that will undoubtedly continue.

References

- Arrow, K. J. & Fisher, A. C. (1974). Environmental preservation, uncertainty, and irreversibility. *Quarterly Journal of Economics*, 88, 312-319.
- Becker, G. S. (1993). Nobel lecture: The economic way of looking at behavior. *Journal of Political Economy*, 101, 385-409.
- Bockstael, N. E. & McConnell, K. E. (2007). Environmental and resource valuation with revealed preferences: A theoretical guide to empirical models. Vol. 7 of I. J. Bateman (Ed.), *The Economics of Non-Market Goods and Resources* series. Dordrecht, The Netherlands: Springer.
- Braeutigam, R. R. & Noll, R. G. (1984). The regulation of surface freight transportation: The welfare effects revisited. *Review of Economics and Statistics*, 66, 80-87.
- Carson, R. T. (2012). Contingent valuation: A practical alternative when prices aren't available. *Journal of Economic Perspectives*, 26 (4), 27-42.

²¹In Chap. 5 of their book, Bockstael and McConnell (2007) provided an excellent overview of welfare measures in discrete-choice models.

- Carson, R. T., Flores, N. E. & Mitchell, R. C. (1999). The theory and measurement of passive-use value. In I. J. Bateman & K. G. Willis (Eds.), *Valuing environmental preferences: Theory and practice of the contingent valuation method in the US, EU, and developing countries* (pp. 97-130). Oxford, United Kingdom: Oxford University Press.
- Cicchetti, C. J. & Wilde, L. L. (1992). Uniqueness, irreversibility, and the theory of nonuse values. *American Journal of Agricultural Economics*, 74, 1121-1125.
- Diamond, P. A. & Hausman, J. A. (1994). Contingent valuation: Is some number better than no number? *Journal of Economic Perspectives*, 8 (4), 45-64.
- Feenberg, D. & Mills, E. S. (1980). *Measuring the benefits of water pollution abatement*. New York: Academic Press.
- Fisher, A. C. & Krutilla, J. V. (1975). Resource conservation, environmental preservation, and the rate of discount. *Quarterly Journal of Economics*, 89, 358-370.
- Freeman, M. A. III. (1993). *The measurement of environmental and resource values: Theory and methods*. Washington, DC: RFF Press.
- Graham, D. A. (1981). Cost-benefit analysis under uncertainty. *The American Economic Review*, 71, 715-725.
- Griliches, Z. (1971). *Price indexes and quality change: Studies in new methods of measurement*. Cambridge, MA: Harvard University Press.
- Hanemann, W. M. (1991). Willingness to pay and willingness to accept: How much can they differ? *The American Economic Review*, 81, 635-647.
- Hanemann, W. M. (1994). Valuing the environment through contingent valuation. *Journal of Economic Perspectives*, 8 (4), 19-43.
- Hanemann, W. M. (1995). Contingent valuation and economics. In K. G. Willis & J. T. Corkindale (Eds.), *Environmental valuation: New perspectives* (pp. 79-117). Wallingford, Oxfordshire, United Kingdom: CAB International.
- Hanemann, W. M. (1999). Neo-classical economic theory and contingent valuation. In I. J. Bateman & K. G. Willis (Eds.), *Valuing environmental preferences: Theory and practice of the contingent valuation method in the US, EU, and developing countries* (pp. 42-96). Oxford, United Kingdom: Oxford University Press.
- Hanley, N., Shogren, J. F. & White, B. (Eds.). (1997). *Environmental economics: In theory and practice*. New York: Oxford University Press.
- Hausman, J. A. (1981). Exact consumer's surplus and deadweight loss. *The American Economic Review*, 71, 662-676.
- Hicks, J. R. (1943). The four consumer's surpluses. *The Review of Economic Studies*, 31-41.
- Horowitz, J. K. (1996). Environmental policy under a non-market discount rate. *Ecological Economics*, 16, 73-78.
- Kreps, D. M. (1990). *A course in microeconomic theory*. Princeton, NJ: Princeton University Press.
- Krutilla, J. V. (1967). Conservation reconsidered. *The American Economic Review*, 57, 777-786.
- Maler, K.-G. (1974). *Environmental economics: A theoretical inquiry*. Baltimore, MD: Johns Hopkins Press for Resources for the Future.
- Maler, K.-G., Gren, I.-M. & Folke, C. (1994). Multiple use of environmental resources: A household production function approach to valuing natural capital. In A. Jansson, M. Hammer, C. Folke & R. Costanza (Eds.), *Investing in natural capital: The ecological economics approach to sustainability* (pp. 233-249). Washington, DC: Island Press.
- McConnell, K. E. (1983). Existence and bequest value. In R. D. Rowe & L. G. Chestnut (Eds.), *Managing air quality and scenic resources at national parks and wilderness areas* (pp. 254-264). Boulder, CO: Westview Press.
- Palmquist, R. B. (1984). Estimating the demand for the characteristics of housing. *Review of Economics and Statistics*, 66, 394-404.
- Porter, R. C. (1982). The new approach to wilderness preservation through benefit-cost analysis. *Journal of Environmental Economics and Management*, 9, 59-80.
- Portney, P. R. (1994). The contingent valuation debate: Why economists should care. *Journal of Economic Perspectives*, 8 (4), 3-17.

- Randall, A. & Stoll, J. R. (1980). Consumer's surplus in commodity space. *The American Economic Review*, 70, 449-455.
- Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82, 34-55.
- Schelling, T. C. (1997). Intergenerational discounting. In T. H. Tietenberg (Ed.), *The economics of global warming* (pp. 607-613). Cheltenham, United Kingdom: Edward Elgar.
- Schmalensee, R. (1972). Option demand and consumer's surplus: Valuing price changes under uncertainty. *The American Economic Review*, 62, 813-824.
- Varian, H. R. (1992). *Microeconomic analysis* (3rd ed.). New York: W. W. Norton.
- Vartia, Y. O. (1983). Efficient methods of measuring welfare change and compensated income in terms of ordinary demand functions. *Econometrica*, 51, 79-98.
- Weisbrod, B. A. (1964). Collective-consumption services of individual-consumption goods. *Quarterly Journal of Economics*, 78, 471-477.
- Willig, R. D. (1976). Consumer's surplus without apology. *The American Economic Review*, 66, 589-597.

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