12.2 The theory of environmental valuation

In this section we deal with the theoretical foundations for the techniques that economists have developed for environmental valuation in relation to services to households. The first step in that development is the assumption that environmental services, or indicators relating to environmental services, can be treated as arguments in well-behaved utility functions. This is an important first step as the conditions under which preferences can be represented by well-behaved utility functions are non-trivial, and, as we shall discuss later in the chapter, some commentators argue that preferences over both 'ordinary commodities' and 'environmental commodities' are unlikely, in many cases, to satisfy those conditions. For an account of the axiomatic basis for well-behaved utility functions the reader should consult a microeconomics text such as Kreps (1990), or Deaton and Muellbauer (1980) on the theory of consumer behaviour.

In this section we set out the standard theory of environmental valuation, simply assuming the existence of the required utility functions. Given that, we discuss the proper monetary measures of utility change, and the extent to which such measures are, in principle, observable, or can be approximated by measures which are observable. Finally here we discuss the conditions for the use of the indirect methods, and which define existence value. Appendix 12.1 covers much the same ground in a more general and formal way.

12.2.1 Price changes: equivalent and compensating variation

For the purpose of doing ECBA we require an estimate of EC. Given the assumption that the relevant environmental damages affect only consumers, what we require is a monetary measure of the utility changes experienced on account of the environmental damage done by the project. In Chapter 5 we discussed, in relation to the practice of partial equilibrium analysis, consumers' surplus, the area under the demand function minus actual expenditure (see Figure 5.11 and its discussion especially). Given an individual's demand function, we could define individual consumer surplus in an exactly analogous way, and the consumers' surplus discussed in Chapter 5 would be the sum of the individual consumer surpluses. For an individual, the change in consumer surplus can be treated as a monetary measure of the individual's utility change when, for example, the price of some commodity falls. However, this is a valid measure of the utility change only under some restrictive assumptions. It would be required, for example, that the marginal utility of income be constant. Hicks (1941) developed a set of money measures of utility change which do not require such restrictive assumptions, and these are what we use, ideally, to estimate EC. As we shall see, in practice we frequently have to use consumer surplus, and one of the major concerns in the literature is the closeness of it to the proper, Hicksian, measures. We shall use MCS to refer to consumer surplus, where the M is for Marshall, the 19th-century economist who popularised the use of consumers' surplus, the CS part, for welfare analysis.

To begin, we leave aside matters environmental. We wish to obtain a monetary measure of an individual's welfare change arising from a reduction in the price of some good C_1 from P_1' to P_1''. Define a second good, C_2, as the composite good which is all goods other than C_1, let the price of C_2 be unity, and suppose that the individual has a fixed money income, Y_0. The consumer's budget constraint, prior to the price fall, can then be written as:

$$P_1'C_1 + C_2 = Y_0 \tag{12.3}$$

A utility-maximising consumer will choose C_1 and C_2 so as to maximise $U = U(C_1, C_2)$ subject to this budget constraint. The solution is two consumption quantities, C_1' and C_2', and a maximised level of utility U_0, and is illustrated in Figure 12.1. We may interpret the vertical axis as being in units of money income. To see this, note from the budget constraint that if no expenditure took place on good 1 (so $C_1 = 0$), then C_2 is equal to the money income level Y_0.

Now consider the consequence of the price fall of good C_1 from P_1' to P_1''. The budget constraint rotates anticlockwise about the point Y_0 on the vertical axis to the new constraint

$$P_1''C_1 + C_2 = Y_0 \tag{12.4}$$

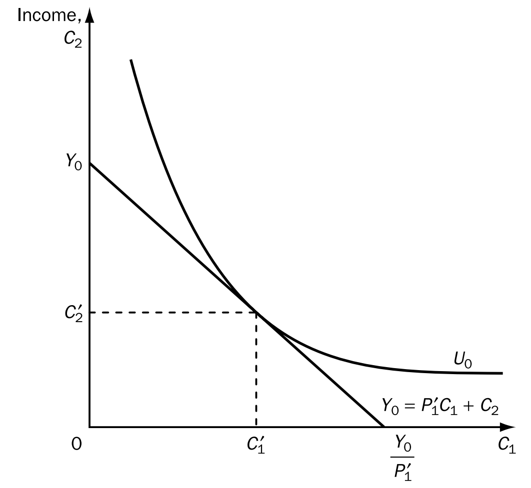


Figure 12.1 Utility maximisation subject to a budget constraint

as shown in Figure 12.2. Utility maximisation now implies consumption levels of C_1'' and C_2'', and a higher utility level, U_1. The increase in the consumption of C_1 from C_1' to C_1'' can be decomposed into a substitution effect, C_1' to C_1^*, and an income effect, C_1^* to C_1''.

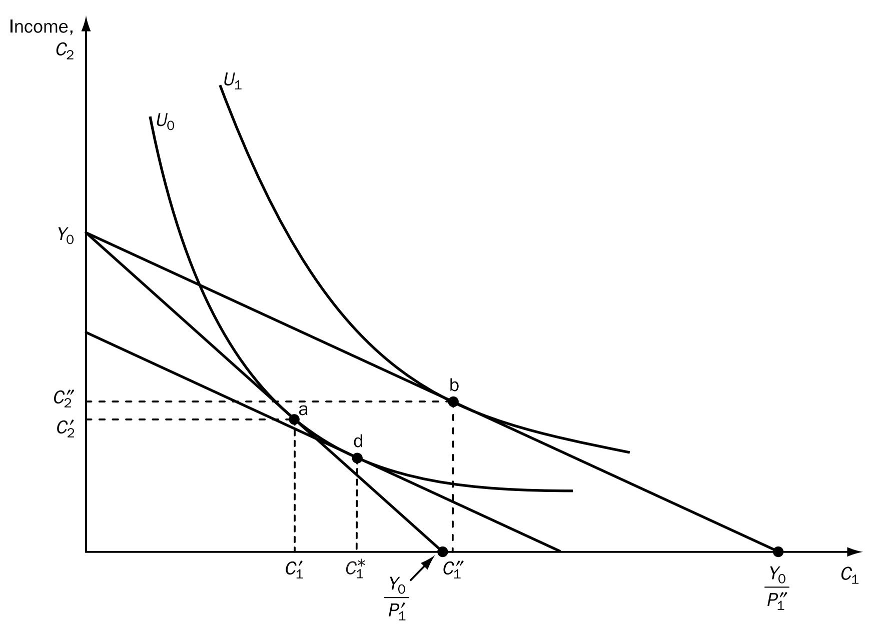


Figure 12.2 The income and substitution effects of a price reduction

There are two 'Hicksian' monetary measures of the utility change associated with a price change:

- The compensating variation (CV) is the change in income that would 'compensate' for the price change.
- The equivalent variation (EV) is the change in income that would be 'equivalent' to the proposed price change.

We will first examine CV and EV for a price fall for good C_1. The CV is the quantity of money income which, when taken from the individual together with the price fall, leaves the individual at his or her initial level of utility. It is, therefore, the maximum amount that the individual would pay to have the price fall occur. The EV is the quantity of money income which, if given to the individual without the price fall, would give the same level of utility as he or she would have attained if the price fall had occurred. It is, therefore, the minimum compensation that the individual would accept in lieu of the price fall.

In Figure 12.3(a) the points labelled a and b denote the utility-maximising consumption choices before and after the price fall. Begin at point b, at which the slope of the budget constraint is given by the final price, after the price fall. Keeping relative prices constant, reduce money income until the individual is constrained to have only the original level of utility, U_0, at the point marked d. The required income reduction is the amount $Y_0 - Y_1$, which is the compensating variation of the price fall. The CV measures, in units of money income, the utility change from U_0 to U_1, given that prices are fixed at their final level. The EV is given by amount $Y_2 - Y_0$ in Figure 12.3(a), leaving the individual at point f, and it measures, in units of money income, the utility change from U_0 to U_1, given that prices are fixed at their initial level. The two variations each measure the utility change from U_0 to U_1 in money-income units. They differ from one another because these changes are valued at different sets of prices and use different reference points.

An alternative geometrical interpretation for CV and EV is given in Figure 12.3(b), where two types of demand function are shown. We know that a price change will, in general, have both substitution and income effects. The Marshallian and Hicksian demand functions shown in Figure 12.3(b) differ in the way in which they deal with these two effects. The Marshallian demand function shows how the quantity of C_1 demanded varies with P_1, when the consumer's income and all other prices are held constant. It is the standard demand function from introductory microeconomics texts. A Hicksian demand function is the relationship between the quantity demanded of a particular good and the price of that good, holding all other prices and utility constant. It is constructed in such a way that compensation is made which eliminates the income effect of a price change. Movements along a Hicksian demand curve thus represent the pure substitution effect of a price change. Hicksian demand functions are sometimes referred to as 'compensated demand functions', and Marshallian as 'uncompensated'.

To derive the compensated demand function for our example, look again at the exercise we undertook in identifying the CV of a price fall, which we showed to be $Y_0 - Y_1$. Now consider the two points a and d in Figure 12.3(a). The move from a to d is the consequence of a fall in the price of the good, holding all other prices constant (in this case just the price of C_2) and holding utility constant (at U_0), and therefore represents the substitution effect of the fall in price of C_1. Points a and d constitute two points on the Hicksian demand curve for $U = U_0$, as shown in Figure 12.3(b). Note that a second Hicksian demand function can be obtained for the utility level $U = U_1$. The two combinations b and f constitute points on this Hicksian demand function.

We are now in a position to provide an alternative geometrical interpretation of CV and EV for a price fall. To do this, the Marshallian uncompensated demand curve and the two Hicksian compensated demands have been redrawn in Figure 12.4. CV is the area to the left of $H(U_0)$ and between the prices P_0 and P_1. EV is the area to the left of $H(U_1)$ and between the prices P_0 and P_1. Note that the area to the left of the Marshallian demand – the Marshallian consumer surplus, MCS, for the price change – is not exactly equal to either of the two Hicksian measures of utility change.

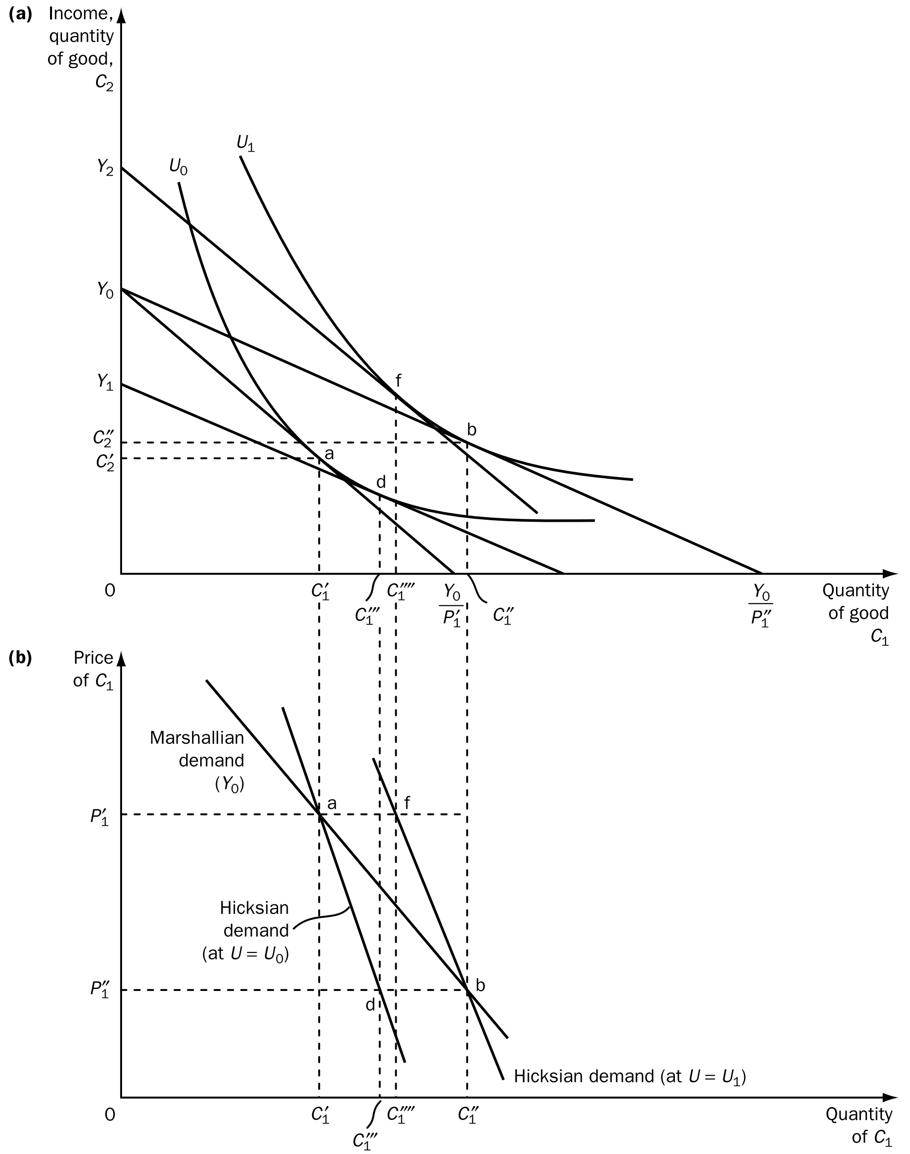


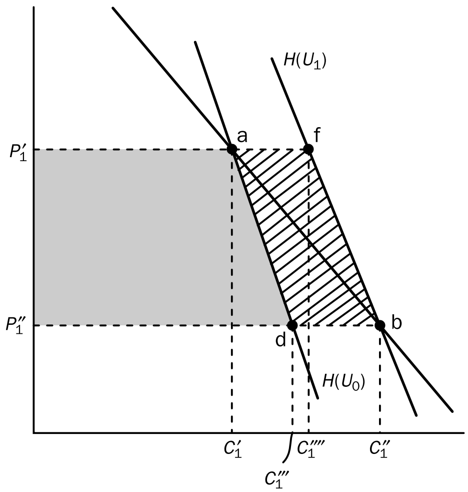
Figure 12.3 (*a*) The compensating variation of a price fall; (*b*) Hicksian and Marshallian demands

For a fall in the price of C_1:

$$\text{CV} = \int_{P_1''}^{P_1'} H(U_0)\,\mathrm{d}P = \text{shaded area}$$

$$\text{EV} = \int_{P_1''}^{P_1'} H(U_1)\,\mathrm{d}P = \text{shaded area} + \text{hatched area}$$

Repeating the arguments that we have gone through for a price fall for a price increase leads to CV for a price increase as the minimum compensation that would leave an individual's utility unchanged, and EV as the maximum that the individual would be willing to pay to have the price increase not take place. Using WTP for willingness to pay and WTA for willingness to accept, Table 12.2 summarises the relationships between WTP/WTA and CV/EV.



For a fall in the price of C_1:

$$CV = \int_{P_1''}^{P_1'} H(U_0)\, dP = \text{shaded area}$$

$$EV = \int_{P_1''}^{P_1'} H(U_1)\, dP = \text{shaded area} + \text{hatched area}$$

Figure 12.4 Compensating variation and equivalent variation

Table 12.2 Monetary measures for price change effects

	CV	EV
Price fall	WTP for the change occurring	WTA compensation for the change not occurring
Price rise	WTA compensation for the change occurring	WTP for the change not to occur

From Figure 12.4 it is clear that for a price fall we have

CV < MCS < EV

which is the same as

WTP < MCS < WTA

For a price increase we get

CV > MCS > EV

or

WTA > MCS > WTP

What this means is that, for the ‘normal’ sort of commodity for which Figures 12.3 and 12.4 are drawn, we have

$$\text{WTP} < \text{MCS} < \text{WTA} \tag{12.5}$$

So, in principle, we can get at proper monetary measures of the utility effects of price changes for an individual if we can ascertain his or her WTP or WTA. If we cannot do that, but we know the individual’s ordinary uncompensated (Marshallian) demand function, we can measure MCS, which we know is not a correct measure for either increases or decreases in price, though we also know that it lies between the two correct measures. Two questions arise. First, which of CV and EV should be used in any particular case? Second, if only MCS is feasible, how wrong will it be in relation to the correct measure?

Taking the second question first, the answer is ‘not very much’. From the foregoing it should be apparent that the size of the error involved in using MCS will depend on the size of the income effect associated with a price change for the commodity of concern, as Hicksian demand functions correct for the income effect whereas Marshallian demand functions do not. It is generally understood, based on Willig (1976), that for most cases of practical concern the error involved in using MCS, with respect to either CV or EV, will be 5% or less. A special case is worth noting. When the income elasticity of demand for the good in question is zero, then the Hicksian demands become identical to the Marshallian demand function, and so EV = CV = MCS. The reason for this is that the income effect of the price change is zero.

The answer to the first question is that it depends on the circumstances and purposes of the analysis. If we think about it in terms of using WTP or WTA, it is really a question of whether we want to treat the status quo as a reference point to which the individual has some kind of entitlement, or not. We shall return to this question in the context of a discussion of monetary measures of changes in the consumption levels of environmental services, which is the subject of the next subsection. It will also come up again in our discussion of contingent valuation, a technique which seeks to directly ascertain WTP or WTA by asking individuals about them.

12.2.2 Quality changes: equivalent and compensating surplus

We now want to consider monetary measures for the utility change implications of changes in the quality or quantity of environmental services. To follow the preceding analysis, let us take C_1 as the environmental commodity, and change the notation from C_1 to E. We are assuming, then, that the individual has a well-behaved utility function $U = U(E, C_2)$. Changes in the level of E can refer to quantity changes or quality changes, depending on the particular environmental service involved. Both usages are encountered in the literature. It is important to be clear that analytically both usages refer to the same thing, changes in the level of E. Where there is reference to 'environmental quality', there is generally some quantitative measure involved, as with, for example, water quality. The measure may be ordinal rather than cardinal, and may be based on subjective evaluations.

Typically, as quality or quantity, E would be non-exclusive and non-divisible, so that the individual cannot adjust his or her consumption level. For present purposes, we shall assume that E is a public good, something like water quality in a lake, say. There are two monetary measures of the utility change associated with a change in the level of E, compensating surplus (CS) and equivalent surplus (ES). They are shown, for the case of an improvement, or increase, from E' to E'' in Figure 12.5(a) and (b) respectively, where the mode of analysis is essentially the same as in the previous subsection.

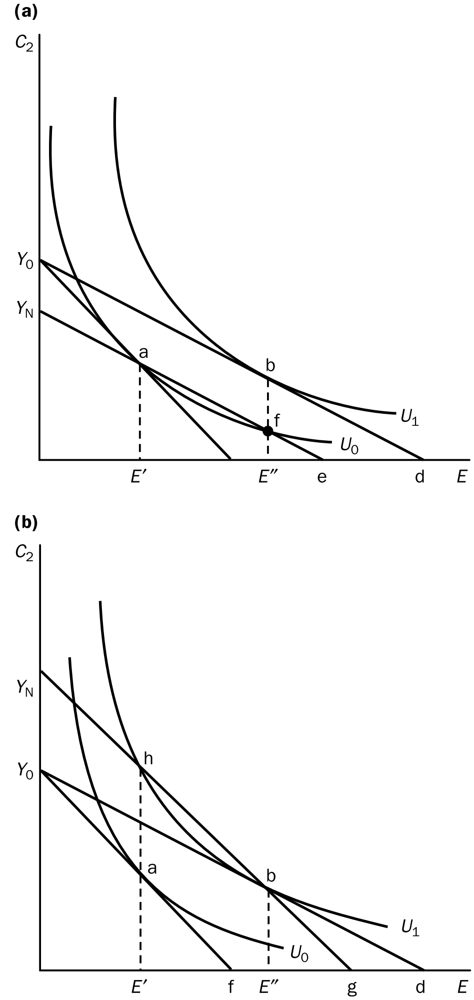


Figure 12.5 Equivalent and compensating surplus

In Figure 12.5(a), the individual is initially at a utility U_0. As a result of some policy change, E increases from E' to E'' and the individual's utility increases. Increasing E with nothing else changing is equivalent to a reduction in the price of E. The slope of the budget line Y_0d gives the price ratio implicit in the quantity increase, tangential to an indifference curve for a higher level of utility, U_1, at b. Now, draw Y_Ne parallel to Y_0d and cutting the indifference curve for U_0 at f where the level of E is E''. This is not a point of tangency, reflecting the fact that the individual is constrained to experience E''. Now CS is bf $= Y_0 - Y_N$, the amount of money that, if forgone by the individual with the policy change, would result in their experiencing the pre-change level of utility. Put another way, it is the maximum willingness to pay for the environmental improvement – if the individual experienced E going from E' to E'' and paid an amount $Y_0 - Y_N$, he or she would remain at a constant level of utility U_0.

Now look at Figure 12.5(b). Again, the increase in E means a move to b with the implicit new price ratio given by the slope of Y_0d. Now draw Y_Ng parallel to the original budget line Y_0f and passing through b. It cuts the indifference curve for U_1 at h. ES is $Y_N - Y_0 =$ ha. It is the amount of money that, at the original prices, would, if paid to the individual, move him or her to the same utility level as the environmental improvement would have done, given

Table 12.3 Monetary measures for environmental quality changes

	CS	ES
Improvement	WTP for the change occurring	WTA compensation for the change not occurring
Deterioration	WTA compensation for the change occurring	WTP for the change not to occur

that the improvement does not, in fact, take place. Put another way, ha is the individual's minimum willingness to accept compensation for the prospective environmental improvement not happening.

If we consider a deterioration in the environment, a reduction in *E*, and examine CS and ES for that case, we find that CS is willingness to accept compensation for the lower *E* while ES is willingness to pay to avoid it. Table 12.3 summarises the situation in regard to monetary measures of the utility changes associated with changes in the quality/quantity of an environmental service, paralleling Table 12.2 for changes in the price of some commodity (which could be an environmental service that is not a public good).

In the case of Table 12.2 we made statements about the relative sizes of CV, EV and MCS. Until recently it was thought that similar statements could be made about CS, ES and MCS for a change in environmental quality. Since the publication of Bockstael and McConnell's paper (1993) it is realised that this is not the case – the results for CV, EV and MCS do not carry over to CS, ES and MCS. This means that for environmental quality changes it is not possible to use MCS as an approximation for the proper monetary measure of utility change.

Given that environmental quality is generally an unpriced public good, so that ordinary Marshallian demand functions cannot be estimated, the inability to say anything about MCS as an approximation to a proper measure would appear to be a non-problem. If MCS itself cannot be estimated, it might appear that it does not really matter that we do not know how it relates to CS and ES, so that the Bockstael and McConnell results are of little interest. However, their results are seen as important in relation to the indirect methods for environmental valuation, the theoretical basis for which we discuss next.