Part 5

Building Economic Foundations

Chapter

11

Public Goods

Government is a contrivance of human wisdom to provide for human wants.
Men have a right that these wants should be provided by this wisdom.

Edmund Burke, *Reflections on the Revolution in France*

Framework for Analysis of Public Goods ♦ Efficient Supply of Public Goods ♦ Revealed Preference Methods of Valuation ♦ Stated Preference Methods of Valuation ♦ Valuation Methods: Applications and Conclusions

A non-excludable good
People cannot be excluded from consuming the good

A non-rival good
One person's consumption of the good does not reduce the availability of the good to others

Public goods are the basis of the state. Public goods include all the services that are required for a state to function: defence, law and order, rules of property and contracts, social and economic infrastructure, basic education and health services, waste collection services and many other services that provide collective as well as private benefits that markets for one reason or another are unlikely to provide.

As discussed in Chapter 4, public goods are technically goods that are non-excludable or non-rival in consumption. Some public goods have both attributes. A good is **non-excludable** if, when supplied to one person, another person cannot be excluded from consuming it or, more broadly, benefiting from it. A good is **non-rival** when one person's consumption of the good does not diminish the supply of the good to others. These characteristics create market failures. Non-excludable goods are under-supplied. Non-rival goods are under-consumed.

Given the fundamental role of public goods in the economy, the provision of public goods is discussed in many parts of this book. In this chapter we start by setting out how the range of issues relating to the provision of public goods is dealt with in this text. We then focus on two prime issues: how to determine efficient quantities of non-excludable and non-rival goods and the related issue of methods for estimating the value of public goods.

Framework for Analysis of Public Goods

The major tasks in the analysis of public goods along with their places in this text are outlined in Table 11.1. The starting point is the definition of public goods and an analysis of market failures, which generates a potential role for government. Given that markets do not produce efficient quantities of public goods, we need set out how efficient quantities can be determined. As usual, the efficient quantity for any good depends on the social benefit and cost of an extra unit of the good.

Table 11.1 Analysis of public goods

Task	*Main features*	*Main text references*
1. Define public goods	Non-excludability or non-rivalness or both	Chapter 4
2. Identify market failures	Public goods are not supplied or supplied inefficiently	Chapters 4, 11
3. Set social objectives	Definitions of efficiency and optimal quantities (including considerations of equity)	Chapter 11
4. Demand estimation	Principles and issues in estimation of preferences	Chapters 6, 11
	Main methods of estimation of preferences	Chapter 11
5. Cost estimation	Principles of cost estimation	Chapter 8
	Methods for estimating costs of production	Chapter 16
6. Evaluation	Usually an application of cost–benefit analysis	Chapter 8
	Education, transport and health applications	Chapters 12, 19, 24
7. Assess supply options	Various ways to provide public goods	Chapter 16
	Pricing, financing and ownership issues	Chapters 17,18
	Central or local supply of public goods	Chapter 33

However, in the absence of a market there is no readily observable demand or willingness to pay for public goods and therefore no clear measure of benefits. When a good is non-excludable, individuals have an incentive to free ride and to misstate their preferences for the good. Accordingly, economists have done a large amount of work on ways to elicit the true values that people attach to non-market goods. These methods fall into two main categories, revealed and stated preferences, which we discuss below. These methods are critical for establishing the value all forms of public goods, including natural environmental goods.

Various issues also arise in estimating the costs of supplying goods. These issues include determining the inputs needed to produce varying levels of output, the allocation of joint costs, the estimation of fixed, variable and average costs and the allocation of capital expenditure over time. These issues are taken up in Chapter 16.

Once benefits and costs are estimated, an overall method of evaluation is required. Cost–benefit analysis (CBA, Chapter 8) provides a general evaluation method for determining an efficient output of public goods. Chapters 12, 19 and 24 describe how CBA can be applied in the education, transport and health sectors respectively. However, as we saw in Chapters 7 and 8, equity objectives may need separate assessment.

Given that an appropriate quantity of a public good is determined, the best way to supply the good must be determined. Public goods may be supplied by:

- public production of publicly financed goods;
- contracting private firms to supply publicly financed goods;
- subsidising private firms to increase their output of specified goods; and
- subsidising consumers of specified goods.

The best way to supply public goods may vary with the degree of market failure, the nature of the good (whether it is a pure public good or a mixed public–private good), the amount of competition among potential suppliers and the competence of government. Much depends on the excludability attributes of the public good. Therefore, there is no single prescription of the provision of goods with public good attributes. In any case, the possibility of government or regulatory failure should be weighed against market failures. General options for the supply of various kinds of public goods are discussed in Chapters 16 and 18 as well as specific issues in education and health (Chapters 12 and 24).

Another important characteristic of many public goods is their spatial dimension. Even the provision of internal security services will vary across the country. Services such as libraries, swimming pools and street lighting are local public goods. Residents of other areas are excluded by geography from enjoying these services. As discussed in Chapter 33, local government may supply these local public goods more efficiently than central government.

Finally, local private clubs may also provide non-rival local public goods. Private clubs can exclude people, but once someone becomes a member, he or she can usually use the facilities free of charge. This is efficient when use is non-rival. However, these solutions are not available when goods are non-excludable. They may also be considered inappropriate when the exclusion process rations access by fees that excludes low-income persons.

Efficient Supply of Public Goods

As we have stressed in this text, an optimal output of a good depends on efficiency and equity objectives. Efficiency requires that goods should be supplied up to the point where the social marginal benefit from an extra unit of output equals the marginal cost. Using economic valuation, the marginal benefit that someone obtains from a good is measured by what he or she is willing to pay for it. Equity issues are complicated because there is no single definition of, or agreement on, what is equitable. A low-income household may obtain as much or more benefit from a good such as a health service as does a high-income household but not be able to pay as much for it. In such cases government may decide to provide a service free or subsidised to all or selected households. We describe below efficient outcomes separately for non-excludable and non-rival goods. Later chapters discuss meeting equity objectives.

Efficient supply of non-excludable goods

The market demand for private (excludable) goods is the sum of the quantities of the good that individuals want to buy at various prices. In a competitive market the market determines the price and consumers vary the quantities that they purchase. The market demand curve is constructed by horizontal summation of the demand curves. Figure 11.1a shows Amy and Ben's demand for beer (say bottles of beer) as D_A and D_B respectively. At price P_M, market demand is $Q_M = Q_A + Q_B$.

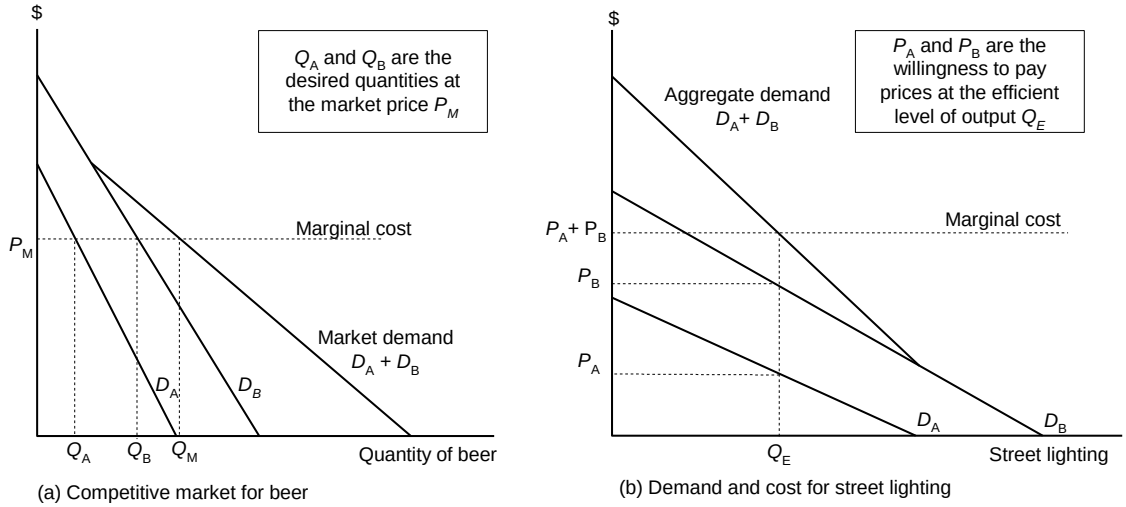

Figure 11.1 Demand and supply for private and public goods

Output Q_M is efficient. Competitive market equilibrium exists where price equals marginal cost (MC). Although Ben has more demand for beer than Amy has, they pay the same price, P_M. It follows that Amy and Ben obtain a similar marginal benefit (MB) from the purchase of one extra beer in that they are willing to sacrifice the same amount of other goods for the extra beer. Therefore, $MC = P_M = MB_A = MB_B$. This satisfies the requirements for Pareto efficiency described in Chapter 3.

On the other hand, when a good is non-excludable, once a good is provided to one household, all households have access to it, though not necessarily equal access and the amount they are willing to pay for it may vary. The collective demand curve is constructed by summing individual demand curves vertically. Figure 11.1b shows Amy and Ben's demands for various amounts of street lighting (D_A and D_B). For an extra unit of lighting at Q_E output, Amy is willing to pay P_A and Ben to pay P_B. Their total willingness to pay (WTP) amount for this extra unit of street lighting is $(P_A + P_B)$.[1]

Efficient supply requires that the amount that individuals are collectively willing to pay for an extra unit of lighting must equal the marginal cost of supplying the unit.[2] The efficient quantity of street lighting is therefore Q_E. This quantity maximises the net social benefit (NSB). The NSB is the area between the collective's demand (WTP) curve and the marginal cost curve. At any other level of output, NSB is lower and there is some inefficiency in resource allocation.

Using the terminology of Chapter 3, pure public goods are supplied efficiently when the sum of the marginal rates of substitution (MRSs) for the good for all individuals is equal to the marginal rate of transformation (MRT). An individual's MRS is the quantity of private goods that he or she is willing to give up for an extra unit of a public good. Total MRS is the total quantity of private goods that individuals are willing to give up for an extra unit of the public good. MRT is the quantity of private goods that must be given up to supply one more unit of the public good. Efficiency requires that the total quantity of private goods that individuals are willing to give up for the public good (ΣMRSs) must equal what they have to give up (MRT). Box 11.1 provides a proof for an economy with two persons and two goods.

Box 11.1 Condition for efficient supply of a non-excludable good[a]

Consider an economy with two individuals, Amy and Ben, and two goods (X is a private good, and G is a public good), where:

$X = X_A + X_B$ *and* $G = G_A + G_B$

A Pareto-efficient outcome exists when Amy is as well off as possible given Ben's level of utility subject to their total resource constraint.

Thus the aim is: Max $U_A\ (X_A, G)$ subject to

$U_B\ (X_B, G) = U^*$ and $X_A + X_B + cG = R$

where c is the cost of the supply of the public good and R is the resource constraint.

This gives a Lagrangian:

$$L = U_A(X_A, G) - \lambda(U_B(X_B, G) - \mu(X_A + X_B + c(G) - R)$$

Maximising L with respect to X_A, X_B and G gives the three first order conditions:

$$\delta L/\delta X_A = \delta U_A/\delta X_A - \mu = 0 \quad (1)$$

$$\delta L/\delta X_B = \lambda\delta U_B/\delta X_B - \mu = 0 \quad (2)$$

$$\delta L/\delta G = \delta U_A/\delta G + \lambda\delta U_B/\delta G - \mu\delta c/\delta G = 0 \quad (3)$$

From (1): $\mu = \delta U_A/\delta X_A$

From (3): $\mu/\lambda = \delta U_A/\delta X_B$

Dividing (3) by μ and rearranging:

$$(1/\mu)\,\delta U_A/\delta G - (\lambda/\mu)\delta U_B/\delta G = \delta c/\delta G$$

Substituting in for μ and μ/λ, we obtain:

$$(\delta U_A/\delta G)/(\delta U_A/\delta X_A) + (\delta U_B/\delta G)\ \delta U_B/\delta X_B = \delta c/\delta G = MRT$$

Note that $(\delta U/\delta G)/(\delta U/\delta X) = MRS_{GX}$

Therefore the Pareto-efficient outcome is where:

$$MRS_{GX}{}^A + MRS_{GX}{}^B = \Sigma MRS = MRT$$

(a) This proof is based on Connolly and Munro (1999, Box 4.1).

[1] It may be noted that Figure 11.1b has a similar structure to Figure 9.1.

[2] Strictly this assumes that the quantity of supply is continuous. If it is discrete, as for numbers of street lights, at an efficient level of supply the willingness to pay for the marginal extra unit may exceed the marginal cost. It also assumes that consumption is non-rival.

Efficient supply of non-rival goods

A key attribute of a non-rival good is that the marginal cost of consumption is zero or very low. Consider, for example, non-rival vehicle trips on roads with no congestion. The marginal cost of road use is zero, except for heavy vehicles that cause road wear and tear. The general principle for efficient pricing is that price should equal marginal cost (see Chapter 17). It follows that efficient use of a lightly trafficked road requires that there should be no charge for use other than for heavy vehicles that cause road wear and tear.

Figure 11.2 shows the demand for trips across a bridge as a function of bridge tolls. It also shows average cost (AC) per trip as a function of trips made. The AC curve shows the toll required at various trip levels to recover fixed construction expenditure (spread over the life of the bridge), assuming no maintenance expenditures. For vehicles with zero marginal user cost, the efficient price would be zero and the efficient quantity of trips would be Q_E. This would maximise the net benefit from use of the bridge. Note that this is below bridge capacity Q_C. If a road toll of say P_1 is charged to cover construction cost, the quantity of trips would fall to Q_1 and the bridge would be under-utilised. The deadweight welfare loss would equal area AQ_EQ_1. Note that with the demand curve shown, P_1 is the minimum toll that a private firm would charge to recover costs. A higher toll could generate economic rent.

We have assumed above that the bridge exists and sought to determine the efficient amount of use. What determines whether the bridge should be built? Using the net social benefit criterion, the bridge should be built if the sum of WTP amounts for use of the bridge equals or exceeds the cost of building and maintaining it in present value terms. Given the demand and cost curves in Figure 11.2 (and no maintenance costs) this condition is satisfied at any level of demand greater than Q_0.

Revealed preference valuations
Inferring an individual's valuations of a good from their behaviour

Revealed Preference Methods of Valuation

We now turn to methods of valuing preferences for public goods, or indeed for any non-market good, and start with revealed preference (RP) methods. Using RP, economists infer individual valuations of goods from observing behaviour. This includes inferring preferences from behaviour in product and factor markets even when there is no specific market for the good. Four main RP methods of benefit valuation are described: use of information from markets, hedonic price analysis, and analysis of travels and defensive behaviour.

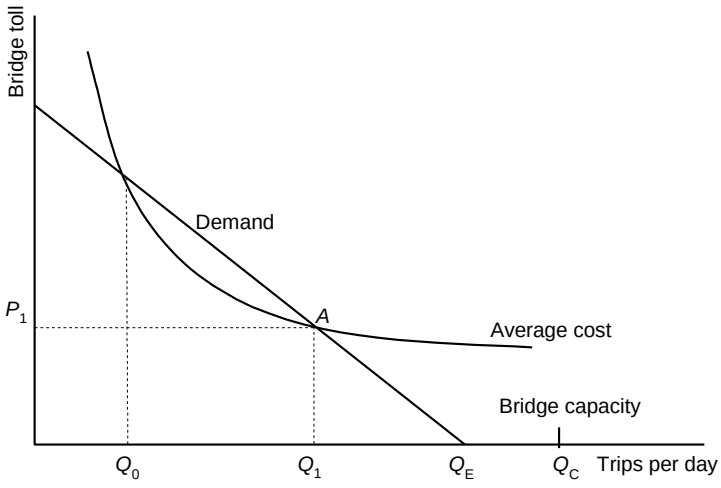

Figure 11.2 Efficient use of a non-rival lightly trafficked bridge

Markets and close substitutes

Markets are often an important source of information about values and costs even when products are not marketed. For example, in Chapter 8 we saw that the value of travel time saved in working hours can be inferred from hourly wage payments. Also, the value of travel time in leisure hours can be inferred from observing individual choices in the use of toll roads or travel modes. Although road users are not being charged directly for the time saved, the value of their travel time savings can be can inferred from the trade-off between the time saved and road toll or the extra cost of the faster mode.

Considering first the benefits of public goods to businesses, these may include savings in expenses, improvements in productivity or increased revenues from increased output. Investment in public goods, such as water or soil quality as well as transport infrastructure, may reduce industry costs and improve productivity. Programs to clean up waterways improve water quality and reduce the costs of water treatment to water supply companies and other users of water. Soil conservation programs improve soil productivity and farm output and reduce farm costs. In each case, the benefit is the sum of any savings from lower costs for existing output plus higher profits from increased output. The value of these benefits can usually be estimated from industry data or, more often, from surveys of the firms involved.

Markets can also provide information about the values of non-marketed goods to consumers. For example, the productivity benefits of a free or subsidised education or training program can be measured by the increases in earnings of the trainees. The productivity benefit component of health care programs can be estimated as a function of the increase in employment and incomes. However, as we will see below, care must be taken to identify the relationships between programs and outputs and sometimes a multivariate hedonic regression equation is required.

The value of other free or subsidised goods may also be inferred from the prices of close substitutes. For example, the value of public housing apartments may be inferred from private market rents. The value of public tennis courts or free public entertainment can be inferred from charges for private courts or prices for similar entertainment respectively. The benefits of reducing water pollution and producing drinking water from the source can be inferred from the price of (similar quality) bottled water. Note, however, that where goods are provided free, some consumers will value them at less than market prices.

In some cases, experimental studies can provide data on valuations. A key feature of experimental studies is that participants are randomly selected (see Rosen and Gayer, 2014, Chapter 2). For example, in the 1980s the US government provided vouchers for housing expenditures to a sample of low-income households to determine whether such vouchers would increase expenditure on housing or on other goods. In 1990 the state of Wisconsin in the United States conducted an experiment in which students who requested to attend private schools were randomly allocated to private and public schools with the aim of eliciting the added value if any of private schools (see Rouse, 1998). Boardman *et al*. (2011) describe several experimental projects designed to elicit WTP values for various policy changes. However social experiments may be expensive valuation methods.

Finally, brief mention should be made of laboratory experiments. These are typically artificially constructed markets in which participants are provided with cash or an endowment of tokens to be allocated to private and public goods under various scenarios. In a review article, Ferraro and Vossler (2010) conclude that ‘decision errors, confusion and noisy behaviour’ are common characteristics of these studies with the implication that findings are at best indicative. In any case, because experiments are usually one-off events in an artificial environment, care must be taken in drawing general conclusions from them.

Hedonic price analysis

Whereas market prices show the values of goods, hedonic price analysis shows the implicit values of the attributes of goods or of access to goods such as schools. Hedonic price analysis can be applied to any good or occupation with multiple attributes. The basic idea is that the value of something is the sum of the value of its attributes.

A common application of the hedonic price method is the valuation of environmental goods through analysis of house prices. This is usually done by a multiple regression study of house prices and their determinants. Consider a general relationship between house prices (P_h) and environmental and other variables,

$$P_h = p\ (S, A, E) \tag{11.1}$$

where S, A and E are sets of structural, access and environmental attributes of houses. If the equation has a linear functional form, the partial derivatives, dP_h/dS and so on, show the implicit price for a unit change in each attribute. If the equation is semi-log form, the estimated coefficient shows the percentage change in house prices as a function of a unit change in the environmental or other attribute. If the equation is log-linear, the estimated coefficients can be interpreted as elasticities.

Turning to examples, many studies (see Boardman *et al*., 2006) indicate that a one unit increase in traffic noise (measured by L_{eq}) causes house prices to fall by between 0.14 and 1.26 per cent per L_{eq}. Other studies show that a 1 per cent increase in suspended particulates (air pollution) causes house prices to fall by between 0.05 and 0.14 per cent. McNair and Abelson (2010) showed that 30 per cent of households in Canberra are willing to pay at least 2.9 per cent of their house values for underground electricity and telephone wires.

Such studies provide estimates of the implicit *marginal* WTP values of many goods. Thus the Canberra result just cited was based on a study in which 30 per cent of households were served by underground wires and 70 per cent with overhead wires. Results may also vary with differences in demand and supply conditions, so care has to be taken in transferring values from one situation to another. Estimated values can be transferred from research studies to policy areas if the environments have similar demand and supply characteristics.

Such methods can also be applied to public goods like schooling, public safety and public transport. Drawing on a house price study in Canberra, Davidoff and Leigh (2008) found that a 5 percentage point increase in test scores is associated with a 3.5 per cent increase in house prices, which is also in line with private tuition costs. They argue that estimating the effects of school quality on house prices provides a measure of the values that parents place on better educational outcomes. Abelson *et al*. (2012) used a house price study in Sydney to infer the values that households attach to lower crime rates and access to rail and bus services.

Hedonic wage studies relate earnings to the attributes of workers and working conditions. These studies can be used to derive the productivity value of education, which depends on the relationship between earnings and education, holding other factors constant (see Chapter 12). They can also be used to infer the value that workers attach to safety, which depends on the wage premium required for more risky occupations.

Hedonic wage studies have been used extensively to estimate the value of safety in the workplace and to infer the value(s) that individuals attach to life (see Box 11.2).

Travel cost studies

Analysis of travel expenditure can reveal the values of non-market goods that involve travel. Figure 11.3 (page 194) illustrates the method. This shows trips per capita per period to a park as a function of trip costs (with no entry fee). The residents of two zones (X and Y) face trip costs of C_X and C_Y and make T_X and T_Y trips per capita to the park. Given enough population zones, a relationship (V_1) between trips per capita and trip costs can be estimated. Note, however, that trip costs are not themselves WTP prices for park visits.

Box 11.2 The value of life

Traditional valuations of life equated the value of life with the discounted present value of output (income) or consumption forgone. However, this is not a revealed preference value. It is an ex-post value of life based on what is lost after the event of death. For most policy purposes, we want to know what individuals are willing to pay to reduce the possibility of early death.

Economists have developed the concept of value of a statistical life (VSL) because most policies reduce the risk of death rather than avert specific deaths. Supposing that people are willing to pay an average (mean) amount of $\$x$ for a one in 5000 reduction in the probability of their death, collectively they would be willing to pay $5000 \times \$x$ to prevent one statistical death. If $\$x$ is $1000, VSL would be $5.0 million.

Economists derive willingness-to-pay values for life in three main ways from: hedonic wage-risk studies, studies of household purchases and stated preference (SP) surveys.

In wage-risk studies, workers are assumed to require income compensation for taking on risk. The wage-risk equation is typically of the following kind:

$$Lnw_i = \alpha_o + \alpha_1 S_i + \alpha_2 X_i + \alpha_i Z_i + \pi F_i + \pi NF_i + \varepsilon_i$$

where w is the wage of worker i, S is years of schooling, X is years of work experience, Z is a vector of family or socio-economic variables, πF and πNF are the probabilities of a fatal and non-fatal injury respectively for worker i and ε_i is an error term. The wage-risk method presumes that workers understand risk differentials, which are often very small, that the model distinguishes between premiums for fatal and non-fatal accidents and that the results are not statistical artefacts of the way in which the model is specified. These strong assumptions, especially the understanding of very small risks, have led some analysts to question the inferences from the studies.

Studies of consumer behaviour infer values of life from decisions to purchase safety devices or choices between safety and travel time. For example, Blomquist *et al*. (1996) estimated the value of risk reduction implied by the use of safety belts, child restraint systems and motorcycle helmets. In order to estimate the true willingness to pay values for risk reduction, these studies may make adjustments for individuals' misperceptions of the true risks as well as estimates of time values.

In stated preference (SP) surveys, people may be asked what they are willing to pay for a reduction in risk or how they would choose between discrete alternatives that include money and safety trade-offs. However, there are concerns that respondents may not give accurate answers to questions involving small risk reductions and that answers may depend on how questions are presented. SP studies have produced a wider range of results than revealed preference studies. However, some recent studies represent sophisticated attempts to deal with these problems, for example Krupnick *et al*. (2000) in Ontario (Canada) and McNair *et al*. (2011) in Sydney.

The results of a large number of studies produce estimates of VSL that range from under US$1.0 million to US$15 million. As discussed in Abelson (2008), the most reliable results are probably in the range of US$3 million to US$5 million (in 2008 prices).

WTP values can be derived as follows. With a linear visitation relationship as in Figure 11.3, a visitor to the park from zone X has an average surplus per trip of $0.5(C_N - C_X)$, where C_N is the trip cost that deters all visits. A visitor from zone Y has an average surplus of $0.5(C_N - C_Y)$. The total value of the park is obtained by summing the surpluses over the populations in all relevant zones.

The trip data, generally obtained by a visitor survey, can also be used to derive a demand curve for the park. The key assumption is that visitors would respond to admission fees as they would to an increase in trip costs. For example, if a fee equal to $(C_X - C_Y)$ were charged, residents of Y would behave like residents of X without an admission charge and trips per capita from zone Y would fall from T_Y to T_X. Summing over all zones, the total number of visitors willing to pay a fee equal to $(C_X - C_Y)$ can be estimated. Other points on the demand curve can be obtained by other notional variations in the admission fee being interpreted as changes in trip costs. In this case, the total surplus for the park equals the area under the estimated demand curve.

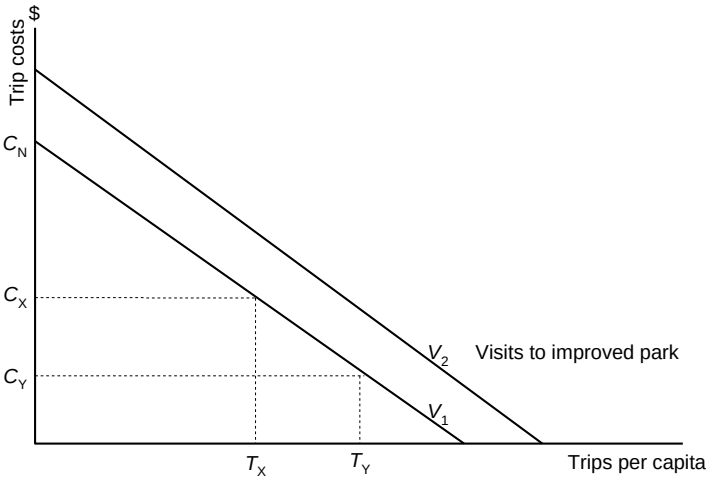

Figure 11.3 Park visits and consumer surpluses

Many studies have employed travel cost analysis to estimate the value of recreational activities. Drawing on over 200 recreational studies in the United States, Walsh *et al*. (1992) estimated that the average value of a recreation day ranged from about $30 for a low quality site to over $70 for a high quality site (in then prevailing dollar values). The highest values were for fishing and non-motorised boating. The lowest values were for camping, picnicking and swimming. Landsell and Gangadharan (2003) employed the travel cost method to estimate the value of urban parks in Victoria (Australia). Rolfe and Dyack (2011) used the method to value recreation in the Coorong (the estuarine region in the mouth of the Murray River in South Australia).

The travel cost method depends on accurate estimates of travel costs, including the value of travel times. Travel time on a recreational trip generally has a lower cost than commuting time. Another critical issue is whether the trip has one or more purposes. If a trip has several purposes, trip costs must be allocated between them. The results may also be sensitive to the functional form of the visitation equation. The size of the benefits is also sensitive to the availability of substitute sites.

In practice, policy makers are often concerned with changes in the quality of a recreational facility rather than with creating or losing a whole facility. Here the analyst must estimate the visits and associated surpluses that would occur with the improved facility (line V_2 in Figure 11.3) or draw on estimated values of activities in similar facilities.

Defensive expenditures

Defensive expenditure is expenditure that averts or mitigates the impact of an event *before* it occurs or expenditure that corrects or reduces damages *after* it is experienced. For example households or communities may construct defences against sea levels rising due to global warming. Alternatively they may accept the damages and incur correction costs after sea levels have risen.

Examples of averting expenditure or behaviour include the use of seat belts and smoke detectors to reduce the risk of injury and death (Blomquist, 1979 and Dardis, 1980 respectively); boiling water or purchasing bottled water to reduce the risk of illness from polluted water supplies (Harrington *et al*., 1989); and installing double glazed windows to

decrease exposure to road traffic noise (Garrod and Willis, 1999). However individuals may also adjust their behaviour to avoid damages. For example they may spend more time indoors on days when air pollutants are a major risk to health. There is no simple way to value this change in behaviour. Households may also be willing to undertake defensive expenditure, say against beach erosion, but be unwilling to do so because their neighbour is unwilling to do so. This is an example of what is known as a weakest link public good (Hirshliefer, 1983).

In principle the value of goods can be inferred from averting expenditures by assuming that a firm or household purchases inputs up to the point where the marginal benefit from a reduction of a unit of the unwanted effect equals the marginal cost. Consider for example double glazing of windows to reduce traffic noise. If each L_{eq} unit of noise reduces household welfare by \$1000, a rational household would be willing to spend \$1000 to reduce noise experienced by one L_{eq} unit. The marginal benefit of noise reduction can be inferred from the observed marginal expenditure of households on noise reduction.

However, the averting expenditure valuation method must be used with care. When expenditure, for example for noise insulation or for air cushions in cars, is lumpy (discrete), households may not be able to make optimising marginal adjustments. Thus the expenditure represents the *minimum* WTP value for the associated noise-free or safety benefit. The *marginal* expenditure associated with a *unit* reduction in pollution is often difficult to estimate. In addition, some expenditure provides joint benefits. For example, double glazing of windows may reduce noise and energy bills. Thus the value of double glazing may be evident but not the separate value of quiet and energy saving.

A generic example of correction expenditure is medical expenses to treat for illnesses arising from air or water pollution. This is often described as the *cost of illness method*. Harrington *et al*. (1989) discuss mitigating expenditures to measure the cost of polluted water supplies. Firms may also incur costs in the treatment of polluted water before using it in various industrial processes.

Watson and Kaksch (1982) estimated the costs incurred to clean buildings in the United States as a result of air particulates. This valuation method is sometimes called the *dose-response method*. The dose is the impact of an event and the response is the cost of restoring the capital value of the asset to its pre-dose state.

In so far as corrective expenditures quite closely restore the individuals or assets to their previous state they represent a WTP figure for the good involved. Of course the corrective expenditure may sometimes fail to restore the good, such as health, and at other times provide for an improvement. Care should be applied especially to hypothetical replacement expenditures, like nutrient replacement for soil loss, when the cost of the expenditure 'cure' may far exceed the cost of the disease.

Stated Preference Methods of Valuation

Stated preference valuations
Eliciting an individual's valuation of a good by asking him or her in various ways to state their preferences honestly

Stated preference (SP) methods of valuation represent the other major approach to estimating individual valuations of public goods. SP methods seek to elicit values for public goods by asking people to state their values or preferred choices.

Traditionally economists questioned whether people would give honest answers to WTP questions. As we saw in Chapter 9, when government proposes to finance a public good by a separate hypothecated (ear-marked) tax, individuals have an incentive to understate what they would be willing to pay for it. On the other hand, when a good is funded from consolidated revenue, potential beneficiaries are likely to overstate their WTP amounts. Either way, as Samuelson observed, 'any one person can hope to snatch some selfish benefit in a way that is not possible under the self-policing competitive pricing of private goods'.[3]

[3] Samuelson (1955, p. 389).

Despite these incentives to free ride (to lie or respond strategically), some economists argue that strategic responses are not a major problem. In early experimental work, Bohm (1972) concluded that most people answer questions honestly. Johansen (1977) and Freeman (1986) also contend that there is little evidence of strategic behaviour. However, most analysts believe that the possibility of strategic behaviour cannot be ignored.

As shown below, it is possible to devise a demand-revealing survey method that, in conjunction with tax payments, eliminates incentives to strategic behaviour. However, this method is not very practical. The contingent valuation (CV) method, in which people are asked in various ways to state their WTP amounts for various goods, is more practical. In recent years economists have also made increasing use of choice modelling (CM) techniques. CM elicits values from respondents' ranking of options, where the options include a monetary component.

Demand revelation without free riding

The demand-revelation method that eliminates strategic behaviour is based on asking individuals to state their WTP dollar values for a public good on two main premises: (1) government will provide the good (or an extra unit of it) if the sum of dollar values exceeds the marginal cost of provision and (2) each individual's payment will equal the difference between the marginal cost of the public good and the sum of the values that everyone else places on the good.[4]

To see how the method works, consider an example. Suppose that a unit increase in the supply of a public good costs $100 and that, apart from Amy, all citizens are willing to contribute $90 for that amount. If Amy is willing to pay $10 or more for the extra unit of the good, it is provided, and Amy will contribute exactly $10. If she is not willing to pay $10 for the extra unit, it will not be provided, and Amy will not pay anything.

We now show why honest revelation is Amy's best strategy. Suppose that Amy's WTP value is $10 but that she does not know the collective sum of other WTP values. Table 11.2 shows seven scenarios in which other people are willing to pay between $80 and $100 for the public good and three response strategies for Amy, giving her true WTP value of $10 and giving false values of $5 and $15. The table also shows the amount that Amy would be required to pay and her net gain in each case. The net gain is the difference between her WTP amount and her actual payment. Honest revelation of $10 is the dominant strategy. If Amy states a WTP amount of only $5, she will be less well off when the collective WTP dollar amounts of others are between $90 and $95, but she obtains no offsetting gain when the

Table 11.2 Gains from honest preference revelation (if Amy's real WTP value = $10)

Sum of others'	*MC ($100)*	*Amy states $10*		*Amy states $5*		*Amy states $15*	
WTP amounts	*less column 1*	*Pays*	*Net gain*	*Pays*	*Net gain*	*Pays*	*Net gain*
100	0	0	10	0	10	0	10
95	5	5	5	5	5	5	5
93	7	7	3	0	0	7	3
90	10	10	0	0	0	10	0
88	12	0	0	0	0	12	−2
85	15	0	0	0	0	15	−5
80	20	0	0	0	0	0	0

[4] This is sometimes described as the Clarke-Groves mechanism or tax after two economists who developed this survey method. Mueller (2003) shows that several other economists contributed to its development.

collective amounts are less than $90 or more than $100. If she states a WTP amount of $15, she risks paying more than the value of the good to her when other WTP amounts total between $85 and $90, but again receives no offsetting benefit.

Rosen and Gayer (2014) show more generally and more formally that this method should generally elicit honest answers (and true preferences). However, it is not necessarily Pareto efficient because the contributions that arise do not guarantee a budget balance. In any case, governments do not finance public goods in this manner and are unlikely to do so. Even if they did, it would be impractical to run regular, complex surveys of this kind. The surveys would be neither easy to understand nor cheap to run.

Contingent valuation methods

In contingent valuation (CV) surveys, individuals are asked to state what they would be willing to pay for a specified good if it were provided. The term 'contingent' denotes that the valuation is based on hypothetical provision of the good.

To elicit answers, a CV survey must first establish the nature of the good to be provided and the 'bid vehicle'. The bid vehicle is the way in which payment would hypothetically be made, for example in user fees, higher local taxes, contributions to a non-profit environmental fund and so on.

The actual question eliciting WTP values can be asked in various ways.

- The most direct way is by **open-ended question**. People are asked simply what they would be willing to pay for a good. However, many respondents find it difficult to answer such a direct question, especially if they lack previous experience of the issue. Analysts tend therefore to use other elicitation methods.
- Using the **payment card** method, interviewers present respondents with a range of WTP values from which to select. However, payment cards may provide implied cue values, including minimum, average and maximum values. This is called **starting point bias.**
- Using the **bidding game** technique, individuals are asked to respond to a specified dollar figure. If the respondent is willing to pay this amount, it is increased until the respondent reaches his or her maximum WTP amount. Conversely, if the respondent declines the initial amount, it is reduced until an acceptable figure is reached. In this case, responses may again be influenced by the starting figures. Potential biases with starting points, as with payment cards, may be overcome at a cost by administering questionnaires with different starting points or payment ranges to separate households.
- With the **close-ended bidding** or **referendum** model, individuals are usually presented with a single payment, which they are asked to accept or reject. This approach is designed to eliminate biased responses, although there is some concern that people are more inclined to answer 'yes' than 'no'. However, it reduces the information provided by respondents and increases the sample size necessary to generate useful information.

As with any survey, there are statistical issues. First, the required sample size may be several hundred households. The size depends on the expected variation in responses, the desired degree of accuracy and the expected non-response rate. Extensive pre-testing of the questionnaire is usually necessary. The second issue is treatment of outliers. Analysts often eliminate extreme bids on the grounds that they are likely to reflect untruthful or erroneous responses. Extreme answers may be culled by employing an arbitrary 5 or 10 per cent cut-off point, using regression techniques to estimate a bid curve or by drawing on subjective judgement more than on statistical science. Third, mean WTP values are required. Estimating mean values from a continuous distribution of WTP values is straightforward. Estimating mean values from data on the proportions of people that would pay particular WTP values requires more complex econometric analysis (Bateman *et al*., 2002). Fourth, there is the issue

of aggregation. Total WTP may be estimated simply by multiplying the estimated mean WTP by the relevant population. If the sampled population is not representative of the total population the relationships between WTP bids and various independent variables, such as income, age or household size, should be estimated and used to calculate the total WTP of the population.

Other issues with CV surveys. As we have seen, strategic bias (exaggeration or lying) is a chronic issue in CV surveys especially when respondents are not required to pay for a good. Respondents may be especially prone to exaggerate when asked what they would be willing to accept as compensation for losses of goods.

Information bias arises when answers depend on the information provided about the environment. Box 11.3 describes a CV study of values for preserving an area in the Kakadu National Park in Australia from mining. The results varied significantly with the information about the possible damages to the park provided respectively by the mining company and the Australian Conservation Foundation.

Part-whole bias arises when respondents fail to distinguish between the value of the whole good and part of it. Kahnemann and Knetsch (1992) reported no significant difference between respondents' mean WTP to protect all lakes in Ontario and one per cent of the lake areas. A related issue is the sequence problem—respondents may state a high WTP for the first good and lower values for subsequent goods.

Box 11.3 Contingent valuation of conservation value of the Kakadu Conservation Zone

The largest CV study in Australia (Imber *et al*., 1991) aimed to estimate the conservation value of the Kakadu Conservation Zone, an area of 50 km^2 surrounded by 20 000 km^2 of the Kakadu National Park for which mining was proposed. Respondents were presented with two scenarios: expected minor and major impacts that reflected the differing views of the mining company and the Australian Conservation Foundation respectively. The impacts related to mine traffic, chemicals used to extract minerals, mine process water and waste rock material.

The sample was 502 respondents from the Northern Territory (NT) and 2034 respondents from the rest of Australia. The latter were a selection of eight people over 18 years of age from a stratified random sample of 256 areas across Australia.

The study employed a two-stage referendum model to elicit WTP values. Individuals were asked: 'Would you be willing to have your income reduced by about $\$X$ a week, that is, $\$Y$ per year, for the next 10 years to add this area to the Kakadu National Park rather than use it for mining?' The starting values used were $5, $20, $50 and $100 a year, with different numbers used for different respondents. If a respondent answered yes/no, he or she was presented with the same question with a higher/lower figure. Whatever the response to the second question, there were no further WTP questions.

The mean WTP answers (in $ per annum) were as follows:

	Scenario	
Area	*Minor damages*	*Major damages*
Rest of Australia	$53 p.a.	$124 p.a.
Northern Territory	$7 p.a.	$14 p.a.

The estimated value of preserving the Kakadu Conservation Zone was between $0.6 billion and $1.5 billion.

Imber *et al* (*ibid*) suggested that the study results were validated by the strong relationships between WTP values and scenario damages, between WTP values and respondent attitudes toward the environment and level of education, and between WTP values and respondent income.

However, the gap between the responses of local residents and others caused problems of interpretation. Some commentators explained that NT residents were well informed; others viewed them as 'rednecks' who did not value the environment. Curiously, respondents from the rest of Australia who had visited the Kakadu National Park also gave lower WTP values than respondents who had never visited the area. This seems to raise the question of information bias.

Diamond and Hausman (1994) reported that when respondents were asked how much they would pay to save whales and seals (in that order) seals were worth (US) $142 and whales $195. When the order was reversed whales were worth $172 and seals only $85. However, surveys can be designed to take account of the budget constraint. Willis and Garrod (1991) identified the respondents' total recreation budget before asking WTP values for the Yorkshire Dales national park.

Hypothetical bias may occur simply because individuals are asked to respond to hypothetical questions. Inaccuracy increases when respondents are asked to value unfamiliar and non-marketed goods. In such cases, an individual cannot learn from the experience of regular purchases.

A major issue in any CV study is the willingness of respondents to accept the premise that they should be willing to pay for something. For example, elderly people eligible for medical benefits in some European countries have been unwilling to state WTP amounts for health services that they receive free of charge. Many responded to CV questions with zeros indicating what they thought they should pay. CV studies are of limited use when respondents perceive that their property rights are threatened.

Together, these biases create significant valuation issues. To some extent, the biases can be minimised by survey design and implementation. Biases such as information and part-whole bias can be reduced by extensively tested survey design and by administering different questionnaires to separate groups. Hypothetical bias may be reduced by larger sample sizes. Strategic bias is harder to deal with.

Importantly, tests are required to assess the validity of any CV study. Validity refers to the degree to which the study measures the intended quantity. Smith (1993) outlines seven tests. These include comparison with outcomes in markets in which goods are actually purchased, consistency with demand theory (e.g. stated WTP should rise at a plausible rate with household income), stability of CV results in test/retest comparisons, laboratory experiments and comparisons of purchase intentions revealed in surveys with actual purchases. The main practical criteria for the acceptability of a one-off CV study are internal consistency of responses, consistency with the predictions of economic theory and consistency with the results of other credible studies dealing with a similar topic in a not dissimilar environment. Box 11.3 reports on some tests of the validity of the CV study in the Kakadu Conservation Zone.

Choice modelling

Choice modelling, like hedonic price analysis, is based on the idea that a good can be defined in terms of its attributes and the levels that these attributes take. For example, a bus service can be defined in terms of its cost, frequency and comfort. Values of these attributes are inferred from these choices.

In CM studies, respondents are asked to choose between alternatives with different attributes including a monetary amount in each case. Typically, respondents are presented with a set of six to twelve choices where each choice set has two options as well as the status quo. An option may contain four or five attributes including a cost attribute. Including more options in a choice set or more attributes in an option may be confusing. Box 11.4 overleaf shows an example of three options in a choice set with each option having five attributes.

Given the choices of the respondents, a CM study models the probability of choosing an option as a function of the utility of that option as measured by its attributes, including cost, relative to the utility (attributes) of other options. In most applications the utility of an option is modelled as a simple linear combination of costs and attributes. The choice of model depends on assumptions about random, non-measured, attributes. If the distribution of random elements is the Gumbel distribution (which is similar to a normal distribution), and the choice is between two options, the estimation model is a binary one.

Box 11.4 Valuing quality using choice modelling

Morrison and Bennett (MB, 2004) used the choice experiment method to estimate the environmental value of rivers in New South Wales. The following is one example of the choice set. Respondents were asked to choose between the following three options for the Bega River. In each case 'not sure' was also a permitted response.

Option (as in MB paper)	*One-off levy on water rates*	*Recreational uses*	*Health of riverside vegetation*	*Native fish*	*Waterbirds and other fauna*
A	None	Picnics Boating No fishing No swimming	Along 30% of river	15 native species present	48 species present
D	$50	Picnics Boating Fishing Swimming	Along 80% of river	21 native species present	59 species present
E	$50	Picnics Boating No fishing No swimming	Along 80% of river	25 native species present	88 species present

Based on the answers to such choices, Morrison and Bennett estimated the following environmental values ($ per household) for the five rivers:

Within catchment values	*Vegetation (per cent of river covered with healthy native vegetation)*	*Fish (per species)*	*Fauna (per species)*	*Fish (across whole river)*	*Swim (across whole river*
Bega	2.32	7.37	0.92	53.16	50.14
Clarence	2.02	0.08*	1.86	47.92	24.73
Georges	1.51	2.11	0.67*	48.19	27.28
Murrumbidgee	1.45	2.58	1.59	53.43	20.35
Gwydir	1.49	2.36	1.89	51.31	60.21

* Insignificant coefficients in model at the 5 per cent level.

If the dependent variable takes three or more values, a multinomial logit model is employed. Taking a choice between two alternatives (Q), the binary logit model may be written as:

$$\text{Log}\,(P_{1Q}/1 - P_{1Q}) = \sum \beta_K X_{KQ} \tag{11.6}$$

where the left-hand side is the logarithm of the odds that a representative individual will choose alternative 1, the X_K are the values of the variables (K) relative to the alternative choice and β_K are the parameters to be estimated.

The marginal willingness to pay (MWTP) for any attribute is given by:

$$MWTP = -B_K/\beta_C \tag{11.7}$$

where β_C is the coefficient on cost and B_K is the coefficient on attribute K. Dividing B_K by β_C gives the monetary value of an extra unit of the attribute K. In general, in a discrete choice model that is linear in the attributes, the marginal rate of substitution between two attributes is

given by the ratio of the coefficients of the attributes. This result is frequently used to derive estimates of WTP for an improvement in a given attribute.

CM can be viewed as a natural extension of discrete binary choices between proposals and monetary values in a CV study. In a CM study the analyst has more scope to vary the trade-offs between levels or attributes of a good and money and can thus obtain more detailed estimates of the components of value. Also, because the monetary component is less explicit in CE studies, respondents may respond less strategically to the choices offered.

However, respondents do not always find it easy to respond consistently to the complexity of choices offered in CM studies and may make inconsistent choices. Day and Prades (2010) show that there are ordering effects, with answers depending on the order of the choices presented. Also, some of the problems encountered in CV studies, such as hypothetical bias, information bias and the willingness of respondents to accept the choices on offer, may arise again in CM studies.

Valuation Methods: Applications and Conclusions

Table 11.3 shows examples of public goods and relevant valuation methods.[5] The goods include educational and health services, safety, transport services, recreational facilities and environmental goods.

As can be seen, RP valuation methods of one kind or another are available for all the benefits shown. The main strengths and weaknesses of the methods are shown in Table 11.4 overleaf.

Table 11.3 Examples of public goods, benefits and valuation methods

Nature of public good/benefit	*Revealed preference method*	*Stated preference*[a]
Educational skills/training	Hedonic wage analysis	
Value of life	Hedonic wage analysis Expenditure on safe products	CV/CM
Value of health	Increased earnings Defensive expenditures Savings in medical expenditures	CV/CM
Police protection/safety	Hedonic property price analysis	CV/CM
Travel time savings (work)	Value of increased output	
Travel time savings (leisure)	Analysis of travel choices	CV/CM
Reductions in vehicle operating costs	Savings in expenditures	
Active recreational facilities	Prices of substitutes	CV/CM
Passive recreational areas	Travel cost analysis	CV/CM
Environmental inputs to production	Reduced costs of production Profits from increased output	
Environmental amenities	Hedonic property price analysis	CV/CM
Flood/fire protection	Hedonic property price analysis Savings in expenditures	CV/CM

(a) CV = contingent valuation; CM = choice modelling.

[5] In recent years, other methods have been developed to value "subjective well-being" (OECD, 2013). These methods apply principally to provision of social welfare services and are discussed in Chapter 22.

Table 11.4 Summary on willingness-to-pay valuation methods

Valuation method	*Main strengths*	*Main weaknesses*
Revealed preferences		
Market data	Easily observable Provides data on productivity	Does not measure non-market goods like quality of life
Hedonic wage method	Provides main market-based method of valuing education, training and safety	Wage premiums are not always a reliable indicator of risk
Hedonic property prices	Has many environmental and other applications and is a reliable method	Requires extensive data on variables affecting prices
Travel cost analysis	Produces reliable answers if site is accessible and study well done	Has to deal with multi-trip purposes and the value of travel time
Defensive expenditure	Provides a useful lower bound to values	Defensive expenditure may have multiple benefits and may not indicate marginal valuations
Stated preference methods		
Contingent valuation	Flexibility in a variety of applications	Answers may be biased if the study is not carried out properly
Choice modelling	Ability to generate a rich data set	May be difficult for respondents to make required comparisons

Stated preference surveys (CV or CM) can also be applied to most kinds of benefits for consumers and indeed to any attribute of any public good. Such surveys can provide information about individual values for most goods. However, because of their hypothetical nature and other issues such as information bias, respondents may not always give accurate or honest answers.

SP surveys require careful design and interpretation. Where possible, the results of such surveys should be supplemented with analyses of revealed preferences in markets or other behavioural situations.

Of course, it is often not feasible to conduct primary research for an economic evaluation. Analysts must then adopt values, modified if necessary, from other studies, especially research studies, rather than undertake a large amount of primary data collection and analysis. However, these values vary with local demand and supply conditions.

Ideally, an analysis of research studies, sometimes called meta-analysis, would provide reasons for any differences in the results between studies, so that the most relevant values can be selected and transferred to the study being undertaken. In the absence of a meta-analysis, it is common practice to adopt mean estimated values from studies that are considered broadly similar (a process known as 'benefit transfer').

In future chapters we will consider how to apply these valuation principles and practices. We will also consider how to deliver public goods. Policies are only as good as their delivery. We will discuss how the best way to supply public goods may vary with the nature of the good (whether it is a pure public good or a mixed public–private good), the degree of market failure, the amount of competition among potential suppliers and the competence (or otherwise) of government.

Summary

- Public goods are goods that are non-excludable or non-rival in consumption. Some public goods are non-excludable and non-rival.
- Public goods include most goods that are necessary for the functioning of the state as well as basic health, education, transport, environmental and many other services.
- This chapter described the efficient provision of non-excludable and non-rival public goods and methods for estimating the value of public (and other non-market) goods.
- Other chapters describe the causes of market failure, methods for estimating costs, the evaluation of public good supply and methods for supplying public goods.
- The supply of a non-excludable public good is efficient when the amount that individuals collectively are willing to pay for an extra unit of the public good equals the marginal cost of supply of that unit.
- Efficient consumption of a non-rival good requires that the price for the good should equal the marginal cost of consumption of the good.
- The valuation of public goods is a critical step in the efficient provision of public goods.
- Revealed preference methods of valuation are based on observations of behaviour in various situations. The methods include the use of relevant market and industry data, hedonic price analysis in product and labour markets, and analyses of travel expenditures and defensive expenditures.
- Stated preference methods obtain individual valuations of goods by survey methods, including contingent valuation and choice modelling methods.
- Between them, revealed and stated preference methods provide the means to value any good or any attribute of a good.
- Future chapters discuss how best to supply public goods. As we will see, the optimal provision of public goods varies with the nature of the good (whether it is a pure public good or a mixed public–private good), the degree of market failure, the amount of competition among potential suppliers and the competence of government.

Questions

1. Consider the services provided by: the Australian Broadcasting Commission, a local police station, public schools, underground power lines, waste collection services and the Tour de France bicycle race. Are these public goods?
2. For the public goods identified in question 1, what methods would you employ to determine the value of a marginal increase in provision of these services?
3. How does efficient provision of a non-excludable and non-rival public good differ from efficient provision of a non-rival but excludable public good?
4. A local government authority wants to determine how many times to clean a residential street per month. It costs \$150 to clean a street. There are 20 houses in the street. Ten households each have a monthly demand for street cleaning equal to $Q^d = 5 - 0.25P$. The other 10 households each have a demand equal to $Q^d = 5 - 0.5P$. Convert these demand curves into estimates of willingness to pay and estimate the efficient number of street cleanings per month.
5. Are strategic responses likely to be a problem in stated preference surveys of individual values for public goods? Do laboratory experiments avoid the problem of strategic responses?
6. Economists often assert that 'there is no such thing as a free lunch'. But they also identify free riding as a major problem for the provision of public goods. Can these positions be reconciled?
7. Suppose that several hedonic house price studies give different values for the cost of noise varying from, say, 0.3 per cent to 1.5 per cent of house price per average dBA above 70 dBA. Would you conclude that the estimates were faulty for some reason (if so, what would the reasons be) or explain the differences in some way?
8. A popular park is located 15 minutes from city *A* and 30 minutes from city *B*. Each city has 100 000 residents with similar incomes and preferences of park amenities. The cost of getting to the park is \$0.50 per minute including vehicle and time cost.

   There are no other users of the park. Residents of city *A* average 10 visits to the park per annum; residents of city B average 5 visits a year. Also suppose that each city pays \$250 000 per annum to maintain the park.

   i. If a linear visitation curve is derived from the two observations of the number of visits, what is (a) the consumer surplus per resident of each city and (b) the total surplus for each city?

ii. Suppose that an urban developer offers $5 million to each city for the park for the purpose of redevelopment; should the park be sold? For the purpose of this question, assume that the park has a potential permanent life and that the real discount rate to apply is 7 per cent per annum.

9. There are three households in a community. Their demand for hours (H) per week of public television is given by $P_1 = 30 - H$; $P_2 = 60 - 2H$; and $P_3 = 70 - H$. Suppose that public television is a pure public good that can be produced at a constant marginal cost of $100 per hour. What is the efficient number of hours of public television?
10. The Department of Health wishes to value improvements in health and asks you to advise on the potential use of contingent valuation and choice modelling techniques for valuing health. What advice would you give?
11. Can public goods, like surf life saving groups, be funded by tax concessions?
12. Is equality of income distribution a public good?

Further Reading

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