Presentation by the Hon. Justice Brian J Preston SC

'Economic Valuation of the Environment'

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Introduction to environmental economics

Human activities impact on the environment. Environmental law is concerned with assessing, approving and alleviating environmental impacts of human activity. Assessment includes statutory requirements for applications for approvals to carry out activities that are likely to impact on the environment to be accompanied by some form of environmental impact assessment of the activity. Approval includes consideration of the impacts of an activity on the environment and measures to be taken to prevent, control, abate, mitigate, remediate or compensate for these environmental impacts. Alleviation includes mitigation or suppression of ongoing environmental impacts that are in breach of the law, and remediation of or compensation for the harm caused.

Economics provides tools to assist in the assessment, approval and alleviation of environmental impacts and their effects. The environment, including its biotic and abiotic components and ecosystems, produces goods and services that are useful to humans because they contribute to the wellbeing, welfare or utility of humans and are therefore valued by humans. For example, the surface waters of a river, lake or wetland provide many goods and services that are valued by humans:

(a) water supply: drinking, cooking, washing and other household uses; manufacturing, power generation and other industrial uses; irrigation of crops, parks and golf courses; and aquaculture;

(b) supply of goods other than water: fish, shellfish, waterfowl and aquatic plant crops; and

(c) non-extractive services: flood control, mitigation and abatement; water transportation; recreational swimming, fishing, boating; and water quality improvements such as pollution dilution and sedimentation.

Human activities that impact on the environment will change the flow of goods and services produced by the environment, and thereby change the welfare or utility of humans. For example, reduction in the flow or levels of waters, or in water quality, will adversely impact on the water supply, the supply of goods other than water, and the non-extractive services available from these surface waters.

It is this change in the flow of goods and services, and in the welfare or utility of humans, that economics attempts to identify, quantify and monetise so as to assess the loss in the welfare or utility and hence in value to humans.

Economics does not value the environment and its components and ecosystems as such, only the changes in the flow of environmental goods and services that are of utility to and are valued by humans. Economics is therefore concerned with the utilitarian value of the environment to humans, not its intrinsic value. Economic valuation of the environment is an anthropocentric concept: it is the value of those environmental goods and services that impact on human welfare.

Economic value: some basic concepts

Economic value concerns trade-offs

Economic value is one of many different ways to define and measure value. Economic value is useful when making economic choices that involve trade-offs in allocating resources, including environmental resources. Measures of economic value are based on individual preferences. People express their preferences through the choices and the trade-offs they make, given certain constraints such as income and available time. Economic value is, therefore, defined in terms of a trade-off.

The economic value of a particular good or service is measured by the maximum amount of another thing (or things) that a person is willing to trade to obtain or give up that good or service. In a market economy, money is a universally accepted measure of economic value, because the amount of money that a person is willing to pay to obtain a particular good or service tells us how much of all other goods and services they are willing to give up to obtain the particular good or service. Money acts as a “numeraire”; a tradeable good in terms of whose value the relative value of other tradeable goods and services are expressed. When an economist states that, for some individual, a good or service (call it X) has a value of $100 (being 100 units of the numeraire of Australian dollars), this means that the individual would be willing to trade or exchange X for $100. Money does not have to be the numeraire used in the trade-off; the numeraire could be a specific commodity or other tradeable good that society considers valuable.

Measuring trade-offs: Willingness to pay and willingness to accept

There are two ways to define the trade-off between a good or service and the units of a numeraire, such as money:

(a) willingness to pay (WTP) measure: the maximum of amount of money the person would be willing to give up to obtain X; or

(b) willingness to accept (WTA) measure: the minimum amount of money the person would be willing to accept as compensation to forego X.

All measures of economic value can be shown to be measures of WTP or WTA.[1]

The environmental good or service X could be a market commodity in which case there will be a market price. However, the environmental good or service could be a non-market commodity, in which case there will be no market price for X. The economic measures for value then become a statement of the trade-off that a person

[1] Hanemann WM and Adamowicz WL, “Economic Concepts for NRDA: Resources, Services and Economic Value”, (Lecture and Powerpoint presentation to 2008 Asian Justice Forum on the Environment: Workshop on Natural Resource Damage Assessment, Nusa Dua, Bali, Indonesia, 22-23 November 2008) slides 55-57.

would make for X, if such a trade-off were to be possible. The measures are, in essence, thought experiments. The measures look to what people reveal they are willing to pay or willing to accept by their other market purchases of related goods or services, or what they are willing to pay or the cost of the actions they are willing to take to avoid the loss of the good or service, or what they state that they would be willing to pay or willing to accept to obtain or not lose the good or service.[2]

The WTP measure and WTA measure may differ depending on what is being valued. For a market commodity, in a perfectly competitive private market, the WTP and WTA measures should be quite close together.[3] For a non-market commodity, such as public goods or amenities, if there are private goods that are readily substitutable for the public good, there also ought to be little difference between an individual's WTP and WTA for a change in the public good.[4] However, if the public good has almost no substitutes (such as a unique threatened species or ecosystem or geomorphologic feature such as Uluru and Kata Tjuta of scenic and cultural heritage), the WTP and WTA measures will differ greatly. One reason is that income or wealth affects or limits the ability to pay. An individual's WTP could be up to but not exceed the individual's entire (finite) income, while the individual's WTA could be infinite.[5] For public goods, therefore, the relation between the two welfare measures of WTP and WTA depends on both a substitution effect as well as an income effect.[6]

The question then arises: which measure should be used? The answer depends on the distribution of property rights.[7] Where a person who suffers a loss of an environmental good or service or a level of environmental quality has a right to that good or service or pre-damage level of environmental quality, the correct measure of value is the WTA measure. Alternatively, if the person has no right to the environmental good or service or pre-damage level of environmental quality, the

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[2] Hanemann and Adamowicz, n 1, slide 58.
[3] Carson RT, Flores NE and Meade NF, "Contingent Valuation: Controversies and Evidence" (2001) 19 Environmental and Resource Economics 173 at 185.
[4] Hanemann WM, "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" (1991) 81 Am Econ Rev 635.
[5] Hanemann, n 4, at 635-636.
[6] Hanemann, n 4, at 646.
[7] Krutilla JV and Fisher AC, *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources* (Resources for the Future, 1975) pp 29-36, 266; Carson et al, n 3 at 174, 187.

better measure is the WTP measure, being the maximum amount the person would be willing to pay to avoid the loss of the good or service or the level of the environmental quality.[8]

For example, if a factory has the potential to discharge waste that would pollute a river used by local people but also would contaminate neighbouring land, different measures might be applied for different people. For the neighbouring land owners who have common law rights not to have their lands contaminated, it would be appropriate to apply the WTA measure so as to ask them how much they would be willing to accept as compensation for the contamination of their land. For the local people who use the river, however, they may have no legal rights to not have the river polluted. It would, therefore, be appropriate to apply the WTP measure so as to ask them what is the maximum amount they would be willing to pay to not have the river polluted.

Application of the WTP measure will generally lead to a lower assessment of value than the WTA measure. One reason is because the WTP measure is bounded by an individual's income or wealth. In the example given, the local people's income is likely to be limited and hence the maximum amount they would be prepared to pay to not have the river polluted would be but a proportion of that limited income. The amount they would be willing to accept to forego having a clean river, however, is not bounded by their income and would be likely to be higher than what they could afford to pay to keep the river clean.

A second reason is that people value losses in environmental quality more highly than equivalent gains.[9] Generally, losses are weighted substantially more than objectively commensurate gains in the evaluation of prospects and trades.[10] Loss aversion will be manifested where people are entitled or perceive they are entitled to (or have been endowed with) an environmental good or level of environmental

[8] Hanley N, "The Economic Value of Environmental Damage" in Bowman M and Boyle A (eds), *Environmental Damage in International and Comparative Law: Problems of Definition and Valuation* (Oxford University Press, 2002) pp 28, 38.
[9] Hanley, n 8.
[10] Kahneman D and Tversky A, "Prospect Theory: An Analysis of Decision under Risk" (1979) 47 Econometrica 263; Tversky A and Kahneman D, "Loss Aversion in Riskless Choice: A Reference-Dependent Model" (1991) 106 Q J Econ 1039.

quality. The endowment effect refers to the increased value of a good to an individual when the good becomes part of the individual's endowment.[11] The consequence of the endowment effect is that an individual will demand more, by way of compensation, to give up an endowed good or level of environmental quality than they would be willing to pay to receive the same good or the level of environmental quality not incorporated into the individual's endowment.[12]

This dependence of the choice of using either the WTP measure or WTA measure on the distribution of property rights creates a further problem where the property is a communal natural resource, not capable of being individually owned, such as the air, running waters, the seas and the sea shore. These are public goods. Because individual property rights cannot be distributed for such communal natural resources, this might suggest that it is appropriate to use the WTP measure for valuing trade-offs in allocating these resources, such as environmental impacts to the resources. The WTP measure may give an underestimate of the value of the resource impacted, because of the lack of substitutes for the resources and the income effect.

However, if the communal natural resources were to be viewed as being owned by the government on trust as part of the public trust, then in principle the WTA measure is the appropriate measure to apply in determining compensation for damage to the communal natural resources.[13] This is what occurs in natural resource damage assessment under United States legislation such as the *Comprehensive Environmental Response, Compensation and Liability Act 1980* (US) and *Oil Pollution Act 1990* (US).

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[11] Thaler R, "Toward a Positive Theory of Consumer Choice" (1980) 1 J Econ Behavior & Organization 39.

[12] Kahneman D, Knetsch JL, Thaler RH, "Experimental Tests of the Endowment Effect and the Coase Theorem" (1990) 98 J Pol Econ 1325 at 1326-1327; Knetsch JL, "Environmental Valuation: Some Problems of Wrong Questions and Misleading Answers" (1994) 3 Environ Value 351 at 352; Kahneman D, Knetsch JL, Thaler RH, "The Endowment Effect: Evidence of Losses Valued More than Gains", Chapter 100 in Plott CR and Smith VL (eds), *Handbook of Experimental Economics Results*, Vol 1 (Elsevier BV, 2008) pp 939, 946, 947.

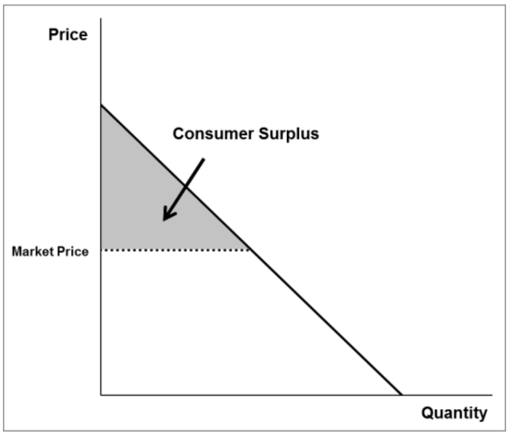
[13] Hanemann and Adamowicz, n 1, slide 62; Carson RT et al, "Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spill" (2003) 25 Environmental and Resource Economics 257 at 281 (footnote 11).

The demand function

In general, when the market price of a good or service increases, people will purchase less of that good or service. This is the law of demand – people demand less of a good or service when it is more expensive (assuming prices of other goods or services and people's incomes have not changed). By relating the quantity demanded and the price of a good or service, the demand function for that good or service can be estimated. The demand function can be represented graphically by the demand curve.[14] Because consumers will pay lower prices the more goods and services they buy, the demand curve slopes downwards.

Consumer surplus: When WTP exceeds price paid

The WTP measure refers to the most a person is willing to pay to obtain a particular good or service (or not have an impact on that good or service). But there may be a difference between what a person is willing to pay and what the person actually does pay for the good or service. This gap between the WTP value and what a person actually pays is called the "consumer surplus". It is graphically represented by the area under the demand curve for a good or service and above its market price.



Demand curve and consumer surplus

The market price of a good or service only tells us the minimum amount that people who buy that good or service are willing to pay for it. When people buy a marketed good or service, they compare the amount they would be willing to pay for that good

[14] King DM and Mazzotta MJ, "Basic Concepts of Economic Value" at http://www.ecosystemvaluation.org/1-01.htm.

or service with its market price. They will only purchase it if their willingness to pay is equal to or greater than the price. Many people are actually willing to pay more than the market price for the good or service and hence their value for it exceeds the market price. In order to make resource allocation decisions based on economic values, we need to measure the net economic benefit from a good or service. For individuals, this is measured by the amount that people are willing to pay beyond what they actually pay. This is the consumer surplus.

For example, if a person spends $100 to obtain an environmental good or service then the person values his or her consumption of that good or service at $100 at the very least. However, the person might value it more than this and be prepared to pay more than $100, say $150. If so, the fact that the person can obtain the environmental good or service for an expenditure less than the maximum the person would be willing to pay yields the person a surplus ($50), analogous to a consumer's profit. The person's expenditure does not measure the value. The expenditure is a lower bound on value (expenditure on the environmental good is $100 but the gross value is $150). To take expenditure as the measure of value would therefore be to underestimate the value of the environmental good or service.

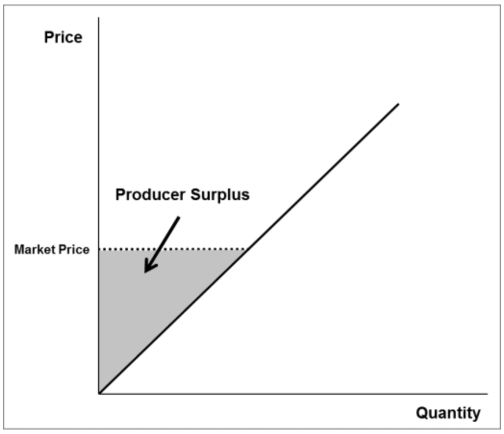
If the person were for some reason prevented from obtaining that environmental good or service (such as because of environmental impacts of a development), the person would suffer a loss of welfare or use and enjoyment. The person loses a consumption experience worth $150 to the person (the gross loss) but saves an expenditure of $100. Therefore, the person's net loss is $50 – the consumer surplus. This is the measure of economic loss – it is the economic measure of the legal concept of loss of use and enjoyment.

The economic benefit to individuals, or consumer surplus, received from a good or service will change if its price or quality changes. If the price of a good increases, but people's willingness to pay remains the same, the benefit received (maximum willingness to pay minus price) will be less than before. If the quality of a good increases, but price remains the same, people's willingness to pay may increase and the benefit received will also increase.[15]

Economic values of goods are also affected by changes in price or quality of substitute goods. Substitute goods are goods that may be purchased instead of a particular good. If the price of a substitute good changes, the economic value for the good in question will change in the same direction. This is because, if the price of a substitute good increases while the price of the good in question remains the same, some people will switch, or substitute, from the substitute good to the good in question. Therefore more of the good in question is demanded and its demand function shifts upward, making the area under it, the consumer surplus, greater.[16]

Producer surplus: when price sold exceeds WTA

Producers of goods and services also receive economic benefits, based on the profits they make when selling the goods and services. Economic benefits to producers are measured by the producer surplus. This is graphically represented as the area above the supply curve and below the market price. The supply function tells how many units of a good or service producers are willing to produce and sell at a given price. The supply curve is the graphical representation of the supply function. Because producers would like to sell more at higher prices, the supply curve slopes upwards.



Supply curve and producer surplus

[15] King and Mazzotta, n 14.
[16] King and Mazzotta, n 14.

If producers receive a higher price than the minimum price they would sell their output for, they receive a benefit from the sale – the producer surplus. The producer surplus is the economic benefit a producer receives by selling its goods or services for a higher price than the minimum price they would be willing to sell their goods or services for.[17]

Total net economic benefit

When measuring economic benefits of a policy or initiative that affects an environment, economists measure the total net economic benefit. This is the sum of consumer surplus plus producer surplus, less any costs associated with the policy or initiative.[18]

Environmental goods and services: some basic concepts

The environment produces some goods that are traded in markets, such as timber from forests and fish from aquatic and marine environments. In other instances, an environmental good or service is used as an input in production, such as clean water. In many instances, however, environmental goods and services may not be directly bought and sold in markets. Nevertheless, these goods and services produced by the environment still have value to humans. To explain how economists approach valuation of these environmental goods and services, it is helpful to explain some concepts concerning environmental services.

Ecosystem functions and services

An environment (such as an ecosystem) has functions and processes, which yield services. Ecosystem functions are the physical, chemical and biological processes that contribute to the self-maintenance of an ecosystem. Examples of ecosystem functions are the provision of habitat for plants and animals and other components of biological diversity, erosion and sedimentation control, nutrient recycling, water purification and carbon sequestration. Ecosystem functions are the constituents of

[17] King and Mazzotta, n 14.
[18] King and Mazzotta, n 14.

the ecosystem that make the flow of environmental goods and ecosystem services possible.

Ecosystem services are the beneficial outcomes, for the natural environment or for humans, that result from ecosystem functions. Examples of ecosystem services are support of food chains and food webs, harvesting of plants or animals, and the provision of clean water or scenic views. In order for an environment (ecosystem) to provide services to humans, some interaction with or some appreciation by humans is required. The functions of the environment (ecosystems) are value-neutral, but the services provided by ecosystem functions do have value to humans.[19]

Market failure in relation to the environment

Decisions about allocation of environmental resources are complicated by various types of market failure. Market failures occur when markets do not reflect the full social costs or benefits of a good or service. For example, the price of fossil fuels (such as coal and oil) do not fully reflect all of the costs, especially environmental costs, that are imposed by combustion of the fuels. Market failures related to ecosystems include the facts that many ecosystems provide goods and services that are public or quasi-public goods; many ecosystem services are affected by externalities; and property rights related to ecosystems and their services are often not clearly defined.[20]

First, environmental services are often public goods. Public goods are non-rivalrous (consumption by one person will not diminish consumption by others) and non-excludable (it is difficult to exclude any person from benefitting from the good).[21] An example is a scenic view from a public place. No matter how many people enjoy the view, others can also enjoy it and no person can be excluded from enjoying the view. Other services may be quasi-public goods, where at a certain level of use, other people's enjoyment may be diminished. An example is a public recreation area,

[19] King DM and Mazzotta MJ, "Valuation of Ecosystem Services" at http://www.ecosystemvaluation.org/1-02.htm.
[20] King and Mazzotta, n 19.
[21] Baker R and Ruting B, *Environmental Policy Analysis: A Guide to Non-Market Valuation* (Productivity Commission Staff Working Paper, 2014, Canberra) p 19; Krutilla and Fisher, n 7, p 23.

such as a national park or the beach. The public recreation area is open to everyone to use and enjoy. However, too many people leads to crowding that can diminish people's enjoyment of the area. The problem with public goods is that, although people value them, no one person has an incentive to pay to maintain the good. Hence, collective action is required in order to produce the most beneficial quantity of the public good.

Second, ecosystem services may be affected by externalities. These are uncompensated side effects of human actions. An externality exists whenever an output of one person appears as an input in the consumption or production of another person without accompanying payment of compensation.[22] An example is if a factory were to discharge waste into and thereby pollute a stream. The discharged waste is an output of the production of the factory. The factory does not pay the cost of containment, avoidance or abatement of the pollution caused by the waste. Rather, the users downstream experience the negative externality of the pollution of the stream, which is an input in their consumption or production activities. The pollution of the stream has a real economic cost to the users. For example, the riparian users such as irrigators may incur input costs in their agricultural production to treat the polluted water by filtration or chemical treatment. Recreational users suffer a diminution in the recreational services provided by the stream. The problem with a negative externality is that the people (and the ecosystems) that are impacted are usually not compensated for the costs they suffer.

Third, if property rights for natural resources are not clearly defined they may be overused, because there is no incentive to conserve them. This is the tragedy of the commons.[23] For example, unregulated fisheries are an open-access resource. Anyone who wants to harvest fish can do so. Because no one person or group "owns" the resources, open access can lead to severe over-harvesting and potentially severe declines in fish abundance over time.

Economic valuation can assist in dealing with the effects of market failures, by measuring their costs to society in terms of lost economic benefits. The costs to

[22] Krutilla and Fisher, n 7, p 27.
[23] Hardin G, "The Tragedy of the Commons" (1968) 162 Science 1243.

society could be imposed, by various means, on those who are responsible (eg the polluter) or can be used to determine the value of actions to reduce or eliminate environmental impacts.[24] In the example of the crowded public recreation area, the benefits to the public could be increased by reducing overcrowding, such as by expanding the area (more space for the same number of people) or limiting the number of visitors (less people for the same area). In the polluted stream example, the benefits from eliminating the pollution can be compared to the costs of actions to reduce the run-off, or can be used to determine the appropriate amounts of fines or taxes to be levied on the polluters responsible. In the open-access fisheries example, the benefits from reducing overfishing can be compared to regulatory costs or the costs to the commercial fishing industry if access is restricted.

Value of ecosystem services

Economists measure the value of environmental (ecosystem) services to people by estimating the monetary amount people are willing to pay to preserve or enhance (or not lose or have diminished) the services. While some goods produced by ecosystems, like fish or timber, may be bought and sold in markets, many ecosystem services, like a day of wildlife viewing or a view of the sea, are not traded in markets. Nevertheless, these services can still be valued in monetary terms. What is required is a measure of how much purchasing power (money) people are willing to give up to obtain the service of the ecosystem, or how much people would need to be paid in order to give it up, if they were asked to make a choice (or trade-off) similar to one they would make in a market.[25]

Process of economic valuation

Economic valuation seeks to measure, in monetary terms, the value people place on environmental goods and services and hence the change in value they experience by the flow of environmental goods and services being impacted. Economic valuation proceeds in four steps: (1) define the scope of analysis; (2) identify all of the physical impacts of the human activity concerned; (3) quantify the identified

[24] King and Mazzotta, n 19.
[25] King and Mazzotta, n 19.

impacts, with and without the human activity; and (4) monetise the identified and quantified impacts to derive the total economic value.[26]

Define the scope of analysis

The first step in economic valuation is to define the scope of the analysis required. Scoping involves, first, ascertaining the purpose for which economic valuation is required. What is the decision that involves trade-offs in allocating resources and what are the trade-offs involved? For courts, there are many legal situations in which economic valuation can arise, including:

(a) granting legal rights, privileges or approvals under legislation to harm, or carry out an activity that harms, the environment: Economic valuation of the environment arises in the process of application for approval of a proposed activity (including in the environmental impact assessment of the activity), consideration of the application (including of the costs and benefits of carrying out or not carrying out the activity and of the principles of ecologically sustainable development such as the polluter pays principle and user pays principle), determination of the application (including, if approval be granted, the conditions to be imposed) and merits review appeals against these decisions;

(b) enforcing legal rights to just compensation for the compulsory acquisition by the government of an interest in land: Economic valuation might arise in the assessment of the market value or special value of the land resumed where the land has environmental characteristics;

(c) remedying legal wrongs that cause harm to the environment: Economic valuation might arise in determining criminal penalties for environmental crime; prevention and restoration orders, civil penalties and administrative orders for civil statutory breaches; monetary damages and injunctions for

[26] Laplante B, “Total Economic Value of the Environment” and “Identify and Quantify Environmental Impacts” (Presentations to EEPSEA Regional Training on Economic Values, Compensation and the Environment, Nusa Dua, Bali, Indonesia, 1-4 December 2014).

tortious wrongs; and compensatory damages and injunctions for breach of the public trust in communal natural resources.

Scoping issues also arise in determining whose costs and benefits should be included in the analysis. This involves geographical scoping (is it the neighbourhood, the local government area, the region, the State, the nation or the globe?) and stakeholder scoping (who are the particular persons whose interests are to be considered?). For example, in assessing the impacts of an open cut coal mine on air quality, for particulate emissions (such as dust), the stakeholders may be the residents and workers in the geographical air catchment impacted by the particulate emissions from the mine but for non-particulate emissions (such as greenhouse gases) the stakeholders would include many more persons in the State, nation and the globe, who are vulnerable to climate change induced events contributed to by greenhouse gas emissions from the mine or from the combustion of the coal mined from the mine. There is a need, therefore, to define the referent group.

Identify all the environmental impacts

The second step is to identify all potential or actual physical impacts of the activity concerned on the environment (as scoped). The conduct can be in the future, such as a proposed activity, or can be in the past, such as conduct that involved the commission of an offence against environmental legislation.

For future conduct, all likely physical impacts of the proposed activity need to be identified, such as air pollution, water pollution, clearing of native vegetation or soil erosion. These generic categories of physical impacts need to be broken down into the specific impacts, such as for air pollution, particulate pollution, including dust and particulate matter of various sizes (such as PM10 and PM2.5), and non-particulate pollution (including greenhouse gases such as carbon dioxide and methane).

Next, the effects of the specific impacts need to be identified. For example, for particulate pollution, the effects may include: particulate deposition on real and personal property and pollution of rainwater tanks; increased incidents of respiratory illnesses, such as asthma attacks; and adverse effects on vegetation, both commercial crops and native vegetation.

For past conduct, the focus is on the generic impacts and the specific impacts and effects that have already occurred or that are likely to occur as a consequence of the conduct.

Quantify the environmental impacts

The third step is to quantify the identified impacts. This involves a comparison between the situation with the conduct concerned and the situation without the conduct concerned. For example, for a proposed activity, the inquiry is, in relation to each specific impact and effect, what is likely to be the situation if the activity is carried out compared to the situation if the activity is not carried out. This need not involve a comparison of the flow of the relevant goods or services in the past compared to the future. This is because factors other than the proposed activity may impact the flow of the goods or services in the future.

For example, assume a proposed activity is likely to have an adverse effect on fisheries in an area (such as water quality or habitat for young fish). However, the fisheries in the area might have been in decline for the last few years for various reasons, such as by overfishing. The impact on the proposed activity is not to be assessed by comparison of fisheries before the activity and after the activity, but rather by a comparison of fisheries in the future with or without the activity. If the fisheries in the future were expected to decline even without the activity, but would be likely to decline even further with the activity, the impact of the activity is the difference between the two rates of decline (ie between expected fisheries with the activity less expected fisheries without the activity). Similarly, if the expected fisheries were expected to improve in the future, perhaps because of other measures being taken to regulate overfishing, the relevant comparator will not be the lower past fisheries but rather the improved expected fisheries without the activity. The impact of the activity will be between this improved expected fishery without the activity and the expected fisheries with the activity.

Monetise the environmental impacts

The fourth step is to monetise the identified and quantified impacts and effects. Monetisation is undertaken because money provides a convenient metric for easy comparison and aggregation. The aim of monetisation is to transform environmental impacts into monetary costs and benefits. The monetised costs and benefits can then be compared and aggregated to make economic welfare decisions. The appropriate method of monetisation of the environmental impacts depends on the types of values of the environmental goods and services that are impacted.

Types of environmental values

Economists classify the values of the goods and services that an environment provides into several types, based on the actual or passive use of an environment. Humans can derive value from actual use of the environment, and its goods and services, but also from non-use or passive use.[27] The distinction arises from the motives generating the value. A use value arises when an environmental resource is valued for motives relating to its current use by an individual, either by consumptive or non-consumptive activities or by obtaining the benefit of services provided by it or relating to the option of using it in the future. A non-use value or passive use value arises when an environmental resource is valued for motives unrelated to the possible use of it by the individual. A person may hold both use values and non-use values for the environmental resource.

Use of an environmental resource can be direct or indirect. Direct use can be consumptive or non-consumptive. Use need not be only in the present, but can also be in the future.

Consumptive direct use value

A consumptive direct use involves extraction, harvesting or consumption of a component of the environment, such as a natural resource. Examples are mining of

[27] Baker and Ruting, n 21, p 4.

minerals, extraction of extractive materials, logging of timber or extraction of non-timber products from forests, harvesting of fish (whether for commercial or recreational purposes) and extraction of water from water sources for irrigation. The consumptive direct use value is the value of the harvested or extracted resource.

Non-consumptive direct use value

A non-consumptive direct use involves use of services provided by the environment without extraction, harvesting or consumption of components of the environment. Examples include using water for transportation or for hydroelectric power production (where the water is returned to the source) and recreational activities in the natural environment, such as swimming, hiking, nature photography, whale watching and bird watching. The non-consumptive direct use value is the value of the non-consumptive activity.

Indirect use value

An indirect use involves the provision of services by the environment, which support and maintain ecological resources, processes and functioning. Examples are storm protection provided by mangroves, nurseries provided to young fish by estuaries, water purification provided by wetlands, and carbon sequestration provided by forests. The indirect use value is the value of these services provided by the environment.

Option value

Goods and services provided by the environment might not be currently used, either directly or indirectly. However, individuals may wish to maintain these environmental goods and services in order to preserve the option of using them (directly or indirectly) in the future. Examples are the maintenance of rainforests to retain the option of the consumptive use of bioprospecting for medicines or the non-consumptive use of a national park in the future. The option value is measured by people’s willingness to pay for retaining the option of directly using the environment in the future for consumptive or non-consumptive purposes or indirectly using the environment by having available the services provided by the environment in the future.[28]

Option values are not a separate element of total economic value; rather, they make up a component of other types of value. So, the option value of future bioprospecting for medicines is a component of direct use value.[29]

Non-use or passive use values

An environment does not have to be used to have value; it can have non-use value. Non-use values refer to all values people hold that are not associated with the use (direct or indirect) of an environmental good or service. Non-use values include altruism value, existence value and bequest value.

Altruism value derives from the satisfaction of knowing that other people have access to the environmental benefits.[30]

Existence value is the value people ascribe to enjoying the knowledge that an environment exists, although they may never personally use it or know that others may use it. For example, a person may be willing to pay to protect a remote natural world heritage area, such as Heard Island or Macquarie Island, even though the person never expects or even wants to go there, but simply because the person values that it exists.[31]

Bequest value is the value people ascribe to enjoying the knowledge that an environment will be available for potential use (direct or indirect) for future generations. Bequest value is measured by people's willingness to pay to preserve an environment for future generations. For example, a person may be willing to pay

[28] Krutilla JV, "Conservation Reconsidered" (1967) 57 Am Econ Rev 777 at 780-781; Krutilla and Fisher, n 7, p 70.
[29] Baker and Ruting, n 21, p 13.
[30] Baker and Ruting, n 21, p 12.
[31] Krutilla and Fisher, n 7, p 15.

to preserve natural world heritage areas so that future generations will have the opportunity to enjoy them.[32]

Total economic value

People may benefit in more than one way from an environment. Thus, the total economic value of an environment is the sum of all of the relevant use values, option values, and non-use values. The total use values will be the sum of the relevant direct use values (both consumptive and non-consumptive), indirect use values and option values. The total non-use values will be the sum of the altruism value, existence value and the bequest value.

Methods of economic valuation

There are different methods of economic valuation to measure the different types of use values and non-use values. The operational distinction between use values and non-use values concerns measurement. A use value will exhibit itself in terms of some form of detectable impact on the consumer's market behaviour – the choices the consumer makes. Non-use value will not exhibit itself in conventional market choice behaviour. It may, however, manifest itself in terms of other behaviours, such as voting for particular public programs or making donations to causes. There are three generally accepted approaches to estimating monetary values of environmental goods and services: market price and productivity methods; revealed preference methods; and stated preference methods. Each approach includes various methods. Rather than undertake fresh valuation studies to estimate economic benefits and values for environmental goods or services, it may be possible to transfer available information about economic benefits and values from studies already completed in another location or context (benefit transfer method). The original valuation study may have used any of the three main valuation approaches.

[32] Krutilla, n 28 at 784.

Market price and productivity methods

The values of some environmental goods and services can be measured using market prices. Some environmental goods, such as fish or timber, are traded in markets. Their values can be measured by estimating consumer surplus and producer surplus (market price method). Other environmental goods or services, such as clean water, are used as inputs in production of a marketed commodity. Their value can be estimated based on the contribution they make to market production using production function methods. The value of environmental inputs can be inferred from the contribution they make to the value of the marketed final product (change in productivity method). These methods measure consumptive direct use values.

Market price method

The market price method estimates the economic value of environmental goods and services that are bought and sold in the market. The market price method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques for measuring the economic benefits from marketed goods or services, based on the quantity people purchase at different prices, and the quantity supplied at different prices. The standard method for measuring the use value of goods and services traded in the market is the estimation of consumer surplus and producer surplus using market price and quantity data. The total net economic benefit, or economic surplus, is the sum of consumer surplus and producer surplus.[33]

A situation in which market price method could be used is where water pollution has caused the closure of a commercial fishing area. A decision needs to be made as to whether it is worth cleaning up the pollution. It will be worth doing so if the benefits of cleaning up pollution in order to reopen the fishing area exceed the costs of cleaning up the pollution. The economic benefit of clearing up the pollution can be

[33] King DM and Mazzotta MJ, "Market Price Method" at http://www.ecosystemvaluation.org/market_price.htm.

calculated by estimating the difference in total economic surplus before the closure and after the closure. This is done by estimating:

(a) the market demand function and consumer surplus for the fish before the closure;

(b) the market demand function and consumer surplus for the fish after the closure;

(c) the loss in economic benefits to consumers, by subtracting the consumer surplus after the closure from the consumer surplus before the closure;

(d) the producer surplus of the producers (commercial fishermen) before the closure;

(e) the producer surplus of the producers after the closure;

(f) the loss in economic benefits to producers, by subtracting the producer surplus after the closure from the producer surplus before the closure; and

(g) the total economic loss due to the closure, being the sum of lost consumer surplus and lost producer surplus, which equates to the benefits of clearing up pollution to reopen the fishing area.[34]

Change in productivity method

The change in productivity method is used to estimate the economic value of environmental goods or services that contribute to the production of commercially marketed goods. It is applied in cases where the goods or services of an environment (or ecosystem) are used, along with other inputs to produce a marketed good.[35]

For example, water quality affects the productivity of irrigated agricultural crops, or the costs of purifying municipal drinking water. The economic benefits of improved water quality can be measured by the increased revenues from greater agricultural productivity, or the decreased costs of providing clean drinking water. In the case of municipal drinking water, cleaner water can be seen to be a direct substitute for other production inputs such as water purification chemicals and filtration. The

[34] King and Mazzotta, n 33.
[35] King DM and Mazzotta MJ, “Productivity Methods” at http://www.ecosystemvaluation.org/productivity.htm.

benefit of having cleaner water flowing into a municipal reservoir is the reduction in costs of treatment by water purification chemicals and filtration.[36]

The change of productivity method is generally applied in the specific case where the environmental impact represents a change in a component of the environment (or ecosystem) that has a consumptive direct use value. This impact will be measured by a change in the production of a good or service for which there is already a market, and therefore market prices. Market prices (or shadow prices, which are market prices corrected for taxes, subsidies or other market imperfections) can be used to assess the economic impact of this change in productivity.

Examples where use of change of productivity method may be appropriate include where water pollution may reduce fisheries yield; sedimentation of a reservoir might impact on hydroelectric power production; floods may impact on agricultural production; and air pollution may impact on health and hence the productivity of the labour force.

An illustration of the application of the change in productivity method would be a reservoir that provides water for a city's drinking water system, which is being polluted by agricultural run-off in the catchment. The change in environmental quality directly affects the cost of producing a marketed good, the municipal drinking water. Cleaner water flowing into the reservoir is a direct substitute for other production inputs such as water purification chemicals and filtration. Hence, the benefits of improved water quality (by eliminating agricultural run-off) can be related to reduced water purification costs.

The change in productivity method proceeds in three steps. The first step is to specify the production function for the marketed good. This is the functional relationship between the inputs and outputs of production. For the example of the reservoir, the inputs are water of a particular quality in the reservoir, water purification chemicals and filtration and the output is the pure drinking water. The

[36] King and Mazzotta, n 35.

production function is the functional relationship between these inputs and this output.[37]

The second step is to establish the dose-response function. This is the relationship between a change in environmental quality of an input (the dose) and the resulting impact on production (the response). In the reservoir example, this would require estimation of how the cost of purification changes when reservoir water quality changes by being polluted by agricultural run-off from the catchment. The analyst would calculate the quantities of purification chemicals and filters needed for different levels of reservoir water quality, by plugging different levels of water quality into the production function. These quantities would then be multiplied by their costs.[38]

The third step is to estimate the economic benefits of an improvement in environmental quality or preventing a reduction in environmental quality. For the reservoir example, this involves estimating the economic benefits of protecting the reservoir from agricultural run-off, in terms of reduced purification costs. If all agricultural run-off is eliminated, the reservoir water will need very little treatment and the purification costs for drinking water will be minimal. This can be compared to the costs of purifying water where run-off is not controlled. The difference in purification costs is an estimate of the benefits of eliminating run-off (and preventing a reduction in environmental quality). Similarly, the benefits for different levels of run-off reduction could be estimated. This step requires information about the projected success of actions to reduce run-off, in terms of the decrease in run-off and the resulting changes in reservoir water quality.[39]

There can be difficulties in using the change of productivity methodology. One difficulty is that the dose-response function may be difficult to establish.[40] In the example of water pollution causing a reduction in fisheries yield, the fisheries yield may not depend only on water quality, but also on a number of other variables. It would be necessary to understand the contribution of each of the variables to

[37] King and Mazzotta, n 35.
[38] King and Mazzotta, n 35.
[39] King and Mazzotta, n 35.
[40] Turner K et al, *Economic valuation of water resources in agriculture* (FAO, Rome, 2004), p 73, available at ftp://ftp.fao.org/agl/aglw/docs/wr27e.pdf.

productivity of the fisheries in order to isolate the impact of changes in the particular variable (eg water pollution) on the reduction in fisheries yield.

Another difficulty is that the relationship between input and output may be difficult to identify if the environmental impact has a long-term effect as opposed to an immediate effect on productivity. For sudden changes in environmental quality, establishing the causal relationship between the change in environmental quality of an input and the change in productivity may be relatively straight forward. However, where the deterioration in environmental quality extends over a long time, it may be difficult to identify a clear causal effect on productivity because the changes might only be small increments over time and because of the influence of multiple other causes that contribute to the change in productivity and confound a clear causal relationship.

Revealed preference methods

The economic value of an environmental good or service is defined as the trade-off that a person would make between the good or service and an amount of the numeraire (eg money). In order to measure the economic value, economists need to find a trade-off through which it can be measured. Where the good or service is not traded in the market, this is done in two basic ways, revealed preferences and stated preferences.

Revealed preference methods aim to provide an economic assessment of environmental impacts by observing the actual behaviour of individuals and what this behaviour reveals about their preferences for changes in environmental quality. Revealed preference methods rely on values leaving a “behavioural trace”; they can therefore only be used to estimate use values and not non-use values (such as existence or bequest values).

Revealed preference methods look for data on choices that people have made in the course of their activities which involve a trade-off between money and the environmental good or service to be valued or something close to it. Revealed preference methodologies are an indirect way of eliciting people's preferences: observed choices made by individuals are assumed to reflect their preferences. These choices are typically market choices where people have the option of buying or not buying something resembling the environmental good or service to be valued. Through their behaviour in making these choices, they reveal their preferences for the environmental good or service.

In the revealed preference methods, however, it is important to recognise that the price paid by people is not the measure of economic value; instead, it is an input to the measurement of economic value. The reason is that the price a person pays for an environmental good or service is not, in general, the maximum amount the person is willing to pay for the environmental good or service. The price is simply the cost to the consumer of the good or service but is not necessarily the maximum amount the consumer would be willing to pay for the good or service.

Hence, when economists use revealed preference methodologies they are not using price to measure economic value. Rather, the price creates a trade-off, and economists are using information about the purchase behaviour to construct an economic model of consumer demand from which they derive an estimate of the person's maximum willingness to pay for the environmental good or service concerned. The willingness to pay estimate comes from the model of demand behaviour, and the assumptions built into it, not from the price per se.

There are a number of revealed preference methods, including: cost of illness; avertive behaviour/defensive expenditure; cost of treatment; hedonic pricing; travel costs; and various methods using costs to estimate benefits such as replacement cost, substitute cost and cost savings methods. Each of these is explained below. Revealed preference methods measure non-consumptive direct use and indirect use values.

Cost of illness method

The cost of illness method is generally applied in the specific case where the change in environmental quality has an impact on human health. The revealed behaviour is the expenditure to treat the illness. Examples are where a reduction in air quality increases the number of asthma attacks, or more water pollution may increase the number of gastro-intestinal diseases.

The cost of illness methodology proceeds in two steps. The first step is to establish the dose-response function, namely, the relationship that exists between a change in environmental quality (the dose) and the resulting impact on health (the response). For the example of air pollution and asthma attacks, this might involve establishing for every increase of 1 microgram/cubic metre of particulate matter of PM10, how many more cases of asthma attacks could be expected.

Once the health impact has been established, the second step is to use market prices (or shadow prices) to estimate the economic costs of treating these health impacts. These costs can be direct or indirect. Direct costs are the costs of seeking treatment, diagnosis of the illness, and treating the illness. The direct medical costs may include the costs of hospital inpatient, physician inpatient, physician outpatient, emergency department outpatient, rehabilitation care, specialists' and other health professionals' care, diagnostic tests, prescription drugs, and medical supplies. The direct non-medical costs may include the costs of transportation to health care services (such as ambulance), relocation and expenses to change diet, house, car etc.

Indirect costs are the costs of a human resource that is lost because of the illness, including the loss of a resource due to morbidity and mortality.[41] There are three primary approaches to estimate indirect costs: the human capital method, the friction cost method, and the willingness to pay method. The most common method is the human capital method, which measures the lost production, in terms of lost earnings, of a patient or a caregiver.[42]

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[41] Seger JE, *Cost of Illness Studies – A Primer* (RTI International, 2006) pp 4-6, 13, 29. See also Hodgson TA and Meiners MR, "Cost-of-Illness Methodology: A Guide to Current Practices and Procedures" (1982) 60 Milbank Fund Q 429.
[42] Seger, n 41, pp 13-14.

The cost of illness method yields a lower bound estimate of the change in environmental quality that impacts human health. It reveals what people actually pay to treat illness, not the maximum amount they would be prepared to pay.

Avertive behaviour/defensive expenditure method

The avertive behaviour/defensive expenditure method is generally applied where the change in environmental quality may have an impact on human health (as for the cost of illness method). However, individuals may undertake expenditures to avoid (avert) becoming ill (ie to prevent the illness instead of treating the illness). The revealed behaviour is the time costs or purchases to avoid harm.

The avertive behaviour/defensive expenditure method is used to estimate values of a change in environmental quality before exposure to health impacts or illness, whilst the cost of illness method is used to value the change in environmental quality after exposure has caused health impacts or illness.

Examples of avertive behaviour are: people buying bottled water to avoid the risk of falling sick by drinking contaminated water; people buying air purifiers to avoid polluted air; motorcyclists wearing a mask to protect themselves from car exhaust fumes; or a worker wearing noise cancelling headphones to block unwanted noise from neighbouring workers. The people’s expenditures on the substitute goods indicate the people’s value of the change in environmental quality.

One study found that bottled water purchases increased in response to publicised water quality violations. Using sales data from a national grocery chain matched with water quality violations, there was an increase in bottled water sales of 22% from violations due to microorganisms, 26% increase in response to violations due to nitrates and 17% from violations due to elements and chemicals. In total, the cost of avertive behaviour was about $60 million for all nationwide violations in 2005, which was likely to be an underestimation of the total willingness to pay to eliminate water quality violations.[43]

The avertive behaviour/defensive expenditure method proceeds in three steps. The first step is to establish the relationship that exists between the change in environmental quality (the dose) and the resulting impact on health (the response). Once the health impact has been established, the second step is to observe how individuals behave to avoid the potential adverse health impact. The third step is to use the estimated expenditures associated with this behaviour (the defensive expenditure) as an estimate (or proxy) of the benefits of avoiding the adverse change in environmental quality. To use the example of contaminated water, a minimum estimate of the benefits of not contaminating the water in the first place would be the total expenditure of individuals to purchase bottled water (the substitute good) to avoid the risk of falling sick by drinking contaminated water.[44]

Cost of treatment method

The cost of treatment method is generally applied in the specific case where individuals aim to offset the adverse change in environmental quality by using additional or complementary inputs in the production of goods and services. The revealed behaviour is the expenditure individuals incur to offset the change in environmental quality.

One example would be if increased sedimentation in a river (perhaps caused by broad-scale clearing of native vegetation and soil erosion in the catchment) increased the costs of a water supply company drawing water from the river because of the need to prevent or control sediment entering the river or remove sediment from the water extracted from the river by physical or chemical means. Another example is that farmers might increase their use of fertilisers in order to offset the impact of soil erosion of the more fertile topsoils on the productivity of the land.

[43] Zivin JG, Neidell M and Schlenker W, "Water Quality Violations and Avoidance Behaviour: Evidence from Bottled Water Consumption" (2011) 101(3) Am Econ Rev 448 at 450-451, also available as NBER Working Paper 16695, January 2011, available at http://www.nber.org/papers/w16695.pdf.

[44] See generally, Turner et al, n 40, p 70.

The cost of treatment method proceeds in three steps. The first step is to establish the production function relationship that exists between the input and the output, including a change in environmental quality. The second step is to use this relationship to assess the quantity of other inputs that must be used to offset the change in environmental quality. The third step is to estimate the economic value of these additional inputs. The market price (or shadow price) of the inputs can be used to assess this economic cost.

The cost of treatment method assesses the cost of substituting environmental inputs for other inputs but does not necessarily assess the values of or society's preferences for the goods and services provided.

Hedonic pricing method

The hedonic pricing method employs differences in the prices of marketed goods or commodities to derive the value of environmental characteristics. Marketed goods can be viewed as comprising a bundle of characteristics, which may include environmental characteristics. Hedonic pricing assumes that people value the characteristics of a good, or the services it provides, rather than the good itself. The differential prices that individuals pay for goods reveal their preferences for different characteristics, including environmental characteristics of the goods. Statistical analysis of the prices and characteristics of the goods is employed to derive an implicit value for the environmental characteristics of interest.[45]

The hedonic pricing method is most commonly used to value environmental amenities that affect the price of residential properties. Hedonic pricing assumes that the expected stream of benefits of living in a residential property is capitalised into the market value of the property. For example, two residential properties in areas popular for water based recreation (such as a lake, river or beach) that differ only in respect of water quality may have different market values, owing to people's preferences for the difference in water quality. Consumers are willing to pay more for the property in the area of higher water quality than the same property in an area

[45] Turner et al, n 40, p 68; Baker and Ruting, n 21, p 28.

with lower water quality.[46] Hedonic pricing uses this difference in value as the implicit price of the difference in water quality. With adequate data and analytical skills it is possible to determine the implicit price for environmental quality for properties that differ in not just one factor but a number of factors.[47]

Take another example of a landfill that has disamenity effects in the form of noise, visual, air (dust and odour), land (contamination and litter) and water pollution. Consumers may be willing to pay less for a house that is located near a landfill than for the same type of house located further away from a landfill. Hedonic pricing can use this difference in value as the implicit price of the difference in environmental quality caused by proximity to a landfill.[48] As a general rule, studies have found house prices increase by 5% to 8% per mile (3% to 5% per km) distance from landfill within a radius of four miles (6.4 kilometres).[49]

The hedonic pricing method involves three steps. The first step is to establish the relationship between the market value of the marketed good (eg a house) and the characteristics of the good. For example, for residential property, the selling prices will depend on the characteristics of the property (such as the lot size, type of house construction, number and size of rooms, number of bathrooms, size of garage etc), the characteristics of the neighbourhood (such as the amenity of the area, quality of schools or crime rates in the area), accessibility characteristics (such as distance to work and shopping centres and availability of public transportation), and environmental characteristics, such as the proximity to desirable environmental

[46] Michael HJ, Boyle KJ and Bouchard R, *Water Quality Affects Property Prices: A Case Study of Selected Maine Lakes* (Maine Agricultural and Forest Experiment Station Miscellaneous Report 398, February 1996, University of Maine) available at http://www.lmvp.org/propvalue/Maine%20Water%20Quality%20vrs%20Property%20Values.pdf; Boyle K and Bouchard R, "Water Quality Effects on Property Prices in Northern New England" (2003) 23 LakeLine 24-27; Maine Department of Environmental Protection, "The Economics of Lakes – Dollars and $ense" at http://www.maine.gov/dep/water/lakes/research.html.

[47] Turner et al, n 40, p 69.

[48] Farber S, "Undesirable Facilities and Property Values: A Summary of Empirical Studies" (1998) 24 Ecol Econ 1.

[49] Cambridge Econometrics, EFTEC and WRc, *A Study to Estimate the Disamenity Costs of Landfill in Great Britain* (Department for Environment, Food and Rural Affairs, London, 2003) pp 10-13, Chart 2.1, available at http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/waste/strategy/legislation/landfill/documents/landfill_disamenity.pdf; Denne T et al, *Recycling: Cost Benefit Analysis* (Final report prepared for Ministry of the Environment by COVEC, April 2007, Auckland, New Zealand) p 20, available at https://www.mfe.govt.nz/sites/default/files/recycling-cost-benefit-analysis-apr07.pdf

amenities (eg water-based recreation area, such as a beach, lake or river) or, conversely, proximity to sources of undesirable pollution or nuisance (such as a landfill).

The second step involves isolating the impact of the environmental characteristic to be valued, such as the quality of the water in the water based recreation area or the distance (say kilometres) away from a landfill, from all other possible variables. The third step is to calculate by how much the market value of the goods concerned (eg house prices) increases for each increment of change in the environmental characteristic (eg each unit of improvement in water quality or each kilometre of distance away from a landfill). The higher price paid by people for a house in an area with higher quality water, or located further away from a nuisance landfill, reflects the value of cleaner water or the absence of the nuisance of a landfill for those people.

Hedonic pricing looks to actual market prices to derive a measure of the marginal value of the environmental characteristics. In the case of property sales, it is important to use actual sale prices rather than estimate values from real estate experts because the market prices reveal consumers' preferences. The choice of properties and their associated prices reflect implicit choices of environmental characteristics linked to the transacted properties.

The data on sale prices are analysed using regression analysis, which relates the price of the property to its characteristics and the environmental characteristic of interest. The effects of different characteristics on the price can therefore be estimated. The regression results indicate how much property values will change for a small change in each characteristic, holding all other characteristics constant.[50]

Travel cost method

The travel cost method is used to estimate economic use values associated with environments that are used for recreation. The method assumes that the value of

[50] King DM and Mazzotta MJ, "Hedonic Pricing Method" at http://www.ecosystemvaluation.org/hedonic_pricing.htm.

the recreational site and its recreational services is reflected in how much people are willing to pay to access the site and use its services. People reveal their preferences by their actual behaviour and choice.

The travel cost method can be used to estimate the economic benefits or costs resulting from eliminating an existing recreational site (such as revoking its reservation as a public recreation area), addition of a new recreational site (eg a newly declared national park), or changes in environmental quality at a recreational site.

The travel cost method attempts to assess the value of changes in environmental services by using the travel costs (including costs of transport, accommodation and entry fees) and the opportunity cost of time that an individual incurs to visit a recreational site, such as a beach, lake or river. It may be inferred that the recreational value of a site must at least exceed the travel and time costs incurred by individuals to visit the site.

The basic premise of the travel cost method is that the travel cost and the opportunity cost of time that people incur to visit a recreation site represents the "price" of access to the site. Thus, people's willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs. This is analogous to estimating people's willingness to pay for a marketed good or service based on the quantity demanded at different prices.[51]

There are various ways of applying the travel cost method, including a zonal travel cost approach, an individual travel cost approach and a random utility approach.[52] At its simplest, the travel cost method proceeds by collecting information on the number of visits to the recreational site from different distances. Because the travel and time costs will increase with distance, this information allows calculation of the number of visits "purchased" at different "prices". This information is used to

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[51] King DM and Mazzotta MJ, "Travel Cost Method" at http://www.ecosystemvaluation.org/travel_costs.htm.
[52] King and Mazzotta, n 51; Turner et al, n 40, pp 67-68.

construct the demand function for the site and then to estimate the consumer surplus or economic benefits associated with use of the recreational services of the site.[53]

Replacement cost/substitute cost/cost savings methods

A natural environmental resource (such as an ecosystem) supplies benefits to society in the form of environmental goods and ecosystem services. Various methods use the costs of replacing the benefits of a natural environmental resource with a human-engineered substitute that supplies the equivalent benefits. These include the replacement cost, substitute cost and cost savings methods.

These methods do not provide strict measures of economic values which are based on people's willingness to pay for an environmental good or ecosystem service. Instead, they assume that the costs of replacing an environmental resource, and the environmental goods and ecosystem services it supplies, provide useful estimates of the value of these environmental goods or ecosystem services. If people incur costs to replace the environmental goods or ecosystem services, then those goods or services must be worth at least what people paid to replace them.[54]

The replacement cost method estimates the benefits of a natural environmental resource based on the costs of replacement with a human-engineered system or restoration of an alternative environmental resource, which will provide the equivalent benefits. The replaced or restored resource is assumed to provide a direct substitute for the original resource.[55] An example would be the cost of a tertiary sewage treatment system as an estimate of the economic value of the nutrient removal service of a natural wetland.[56]

The cost of replacement or restoration can be derived from the actual expenditures or estimated costings. The underlying assumption is that the cost of replacement or restoration equals the benefits (the economic value) that society derives from the

[53] Baker and Ruting, n 21, pp 27-29.
[54] King DM and Mazzotta MJ, "Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods" at http://www.ecosystemvaluation.org/cost_avoided.htm.
[55] Turner et al, n 40, p 72.
[56] Bockstael NE, Freeman AM, Kopp RJ, Portney PR and Smith VK, "On Measuring Economic Values for Nature" (2000) 34 Environ Sci Technol 1384 at 1388.

environmental resource.[57] In the wetland example, the assumed benefits of a natural wetland that has not been damaged or destroyed would be equal to the cost of replacing it with an alternative wetland (perhaps an artificial wetland) or restoring an alternative wetland to an equivalent ecological condition to the natural wetland.

The substitute cost method uses the cost of providing a substitute for an environmental resource (such as an ecosystem), and the environmental goods and ecosystem services it provides, as an estimate of the value of the affected environmental resource or its environmental goods or ecosystems services. For example, the method could be applied to value the flood protection services of a natural wetland by estimating the cost of replacing this service with the use of human-engineered protection such as retaining walls or levees. The cost of building and maintaining the replacement protection structures provides a lower bound estimate of the value of the flood protection service of the wetland.

The replacement cost or substitute cost methods can be a valid measure of economic value only if three conditions are met:

(a) the human-engineered system provides functions that are equivalent in quality and magnitude to the natural function;

(b) the human-engineered system is the least cost alternative way of performing this function; and

(c) individuals in aggregate would in fact be willing to incur these costs if the natural function were no longer available.[58]

The first condition is particularly difficult to fulfil for ecosystems. Perfect substitutes for environmental goods and ecosystem services are difficult to identify. Environmental goods and ecosystem services are subject to increasing scarcity due to severe exploitation. Finding perfect substitutes to replace individual goods or services is becoming more complicated. Valuing the entire ecosystem is even more

[57] Turner et al, n 40, p 72.

[58] Bockstael et al, n 56 at 1388; Sundberg S, "Replacement costs as economic values of environmental change: A review and an application to Swedish sea trout habitats" (Beijer Institute of Ecological Economics Discussion Paper Series No. 184, 2004) pp 4, 20-23, available at http://www.beijer.kva.se/PDF/68407733_Disc184_new.pdf.

difficult. Ecosystems are complex systems and identifying all of the environmental goods and ecosystem services they produce and then finding substitutes for them is difficult. As a consequence, all aspects of the ecosystem tend not to be included when suitable replacement techniques are identified and the estimated replacement cost value will underestimate the true value of the ecosystem.[59]

Natural environmental resources (such as ecosystems), and the goods and services they provide, are not homogenous in quality. For example, the ecosystem services of nutrient or waste assimilation provided by a wetland will differ in quality according to the characteristics of the wetland area. The level of waste assimilation provided by an affected wetland has to be known to facilitate a correct application of the replacement cost method.[60]

The cost savings method is similar to the replacement cost method, but it determines the value of an environmental resource in terms of the savings in costs made through use of a good or service provided by the resource versus the next best (cheapest) alternative source of the good or service. One example is the use of water in rivers or lakes for transportation. The value of using water as a means of transporting goods is measured in terms of the cost savings from not transporting the same goods by an alternative means, such as by train or truck. Another example of the cost savings method is to value hydroelectric power generation by estimating the difference between the costs of generating hydroelectric power and the next cheapest method of power generation (eg coal).[61]

There are similar difficulties with the cost savings method. First, it equates cost savings with value of the environmental resource, which may be an underestimate. Second, it does not assess society's preference by being supplied the good or service via the environmental resource rather than by other means. Third, it does not take into account other differences that arise by supplying the good or service via the other means. In the water transportation example, there may be large differences in time costs in the different transport modes, and in the electricity supply

[59] Sundberg, n 58, p 20.
[60] Sundberg, n 58, p 21; Shabman LA and Batie SS, "Economic Value of Natural Coastal Wetlands: A Critique" (1978) 4 Coastal Zone Mgmt J 231 at 242.
[61] Turner et al, n 40, p 72.

example, there may be large differences in the environmental impacts associated with generating power by hydroelectric power plants compared to coal fired power plants. Fourth, it assumes the demand will be unresponsive to changes in costs, which is unrealistic for goods and services for which there is price elasticity of demand.[62]

Stated preference methods

Many environmental goods and services are not traded in markets and are not closely related to any marketed goods or services. Hence, people cannot "reveal" what they are willing to pay for them or how much compensation they would be willing to accept to forego them through their market purchases or choices. In these cases, surveys can be used to ask people directly how much they are willing to pay to obtain a non-market environmental outcome (such as an improvement in an environmental good or service or in environmental quality) or how much they are willing to accept to forego an environmental good or service or a level of environmental quality, based on a hypothetical scenario (contingent valuation method). Alternatively, people can be asked to make trade-offs among different alternatives (such as different environmental attributes or characteristics at different prices or costs). The people are not directly asked for their willingness to pay or willingness to accept, but this is inferred from trade-offs that include price or cost as an attribute (choice experiment method).

Contingent valuation method

The contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental services. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services. It is called "contingent" valuation because people are asked to state their willingness to pay or willingness to accept contingent on a specific hypothetical scenario and description of the environmental service. The contingent valuation method is referred to as a "stated preference"

[62] Turner et al, n 40, p 72.

method because it asks people to state directly their values, rather than inferring values from actual choices, as the "revealed" methods do. Contingent valuation is, therefore, based on what people state they would be willing to do, as opposed to what people are observed to do. This is both its strength and its weakness.[63]

The contingent valuation method can be used to estimate economic values for all kinds of environments (ecosystems) and environmental services. It can be used to estimate both use values and non-use (passive use) values, but is most widely used for estimating non-use values. Stated preference methods are the only methods of assigning monetary values to non-use benefits of the environment because people's enjoyment of such benefits does not involve market purchases and may not involve direct participation by people. Since people do not reveal their willingness to pay for non-use benefits through their purchases or their behaviour (they leave no behavioural trace), the only option for estimating a value for these non-use benefits is by asking them questions.[64]

Contingent valuation was used to estimate the passive use losses caused by the large scale oil spill from the Exxon Valdez into Prince William Sound, Alaska.[65]

The fact that the contingent valuation method is based on asking people questions, as opposed to observing their actual behaviour, and that it estimates economic value on the basis of how people respond to hypothetical questions about hypothetical market situations, means that great care must be taken in the design and implementation of the survey.[66]

Common to most applications of contingent valuation surveys are: (a) an introductory section which helps set the general context for the decision to be made; (b) the environmental change: a detailed description of the availability or quality of the environmental good in both the reference state (usually the status quo) and the target state (usually with the proposed policy action); (c) the hypothetical market: a

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[63] King DM and Mazzotta MJ, "Contingent Valuation Method" at http://www.ecosystemvaluation.org/contingent_valuation.htm.
[64] Hanemann WM, "Valuing the Environment Through Contingent Valuation" (1994) 8(4) J Econ Perspect 19 at 38.
[65] Carson et al, n 13.
[66] Baker and Ruting, n 21, pp 36-39.

description of the institutional setting (such as the private goods market or political market) in which the environmental good will be provided; (d) payment vehicle: a description of the manner in which the environmental good will be paid for, including the institutions surrounding the payment (eg fees, taxes, levies etc); (e) the elicitation procedure: the method by which the survey elicits the respondents' willingness to pay or willingness to accept decision in a discrete choice framework with respect to the environmental good; (f) debriefing questions about why respondents answered certain questions the way that they did, such as how certain the individual is about their choice, why they chose a particular option and other information about the individual's reaction to the valuation task; and (g) collection of a set of respondent characteristics including attitudes, debriefing questions, and socio-demographic information.[67]

The contingent valuation method proceeds in five steps:[68]

1. Define the valuation problem: What environmental goods or attributes or changes in environmental quality are being valued? Who is the relevant population whose value of the environmental goods or attributes or change in environmental quality is to be estimated? What payment vehicle should be used to connect these people to this environmental outcome? The choice of payment vehicle, such as a compulsory levy versus a rise in existing taxes or consumer prices, can have a significant impact on willingness to pay.[69]

2. Decide how the survey will be conducted: What survey mode should be used to conduct the questionnaire? Should the questionnaire be presented by an interviewer to the respondents in face to face interviews or over the telephone or should it be mailed to and self-administered by the respondents? How large will the sample size be? Who will be surveyed?

3. Design and test the survey instrument: This is the most important and difficult step in the process and may take many months. Developing and testing survey

[67] Carson et al, n 3 at 179; and see generally Mitchell RC and Carson RT, *Using Surveys to Value Public Goods: The Contingent Valuation Method* (Resources for the Future, 1989).
[68] See generally, Hanemann, n 64 at 21-25.
[69] Baker and Ruting, n 21, p 36.

questions that people understand and that will elicit answers that make sense and reveal people's values for the environmental good or attribute or the change in environmental quality is a difficult and time consuming process. The design of the survey instrument (questionnaire) typically has three components. First, it provides an explanation of the environmental issue of interest together with the change in environmental quality. Second, it includes questions regarding people's willingness to pay or willingness to accept. The survey respondents' choice or preference can be elicited in a number of ways, including continuous or open-ended questions, closed-ended questions (discrete choice questions), or use of a "bidding game" approach or payment cards with a list of possible answers. Third, the questionnaire may include questions about the socioeconomic characteristics of survey respondents which enable analysis and verification of the validity of responses on willingness to pay or willingness to accept.[70] The design of the questionnaire may involve an iterative process of initial interviews and focus groups with the types of people who will be receiving the final survey, further focus groups to refine the questions and test different approaches to the valuation questions and different payment vehicles to extract payment for the environmental good or attribute or change in environmental quality to be valued, then pre-testing or pilot surveys of the revised questionnaire;[71]

4. Field implementation of the survey: including selection of survey sample and undertaking interviews by the selected mode; and

5. Compile, analyse and report the results: The data must be entered and analysed using statistical techniques appropriate for the type of questions to estimate the average value for an individual or household in the sample, and extrapolate this to the relevant population in order to calculate the total economic benefits for the environmental goods or attributes or change in environmental quality.

[70] Turner et al, n 40, p 74.
[71] King and Mazzotta, n 63.

Choice experiment method

The choice experiment (or choice modelling) method is similar to the contingent valuation method in that it can be used to estimate economic values for any environment (or ecosystem or environmental service) and can be used to estimate non-use values as well as use values. Like contingent valuation, the choice experiment method asks people to make choices based on a hypothetical scenario. However, it differs from contingent valuation because it does not directly ask people to state their values in dollars. Instead, values are inferred from the hypothetical choices or trade-offs that people make in their survey responses.[72]

The choice experiment method asks the survey respondents to make choices between different options that are made up of sets of environmental attributes or characteristics, with different prices or costs, that describe a policy outcome, such as to state a preference between one group of environmental attributes or characteristics, at a given price or cost to the individual and another group of environmental attributes or characteristics at a different price or cost.

For example, environmental attributes might indicate numbers of birds and fish, or an area of native vegetation, and the cost to the individual or their household. By varying the levels of attributes and presenting people with several choice sets, statistical methods can be used to quantify the trade-offs that people make between attributes (including implicit prices). Implicit prices are estimated for each attribute, reflecting average willingness to pay for an additional unit of the environmental attribute. The value of a particular policy option is the sum of the value of its attributes (the implicit price multiplied by the change in the attribute).[73]

Because it focusses on trade-offs between scenarios with different characteristics, choice experiment method is especially suited to policy or resource allocation decisions where a set of possible actions might result in different impacts on natural resources or environmental services. For example, improved water quality in a lake

[72] King DM and Mazzotta MJ, "The Contingent Choice Method" at http://www.ecosystemvaluation.org/contingent_choice.htm.
[73] Baker and Ruting, n 21, pp 24-25.

will improve the quality of several environmental services provided by the lake, such as drinking water supply, fishing, swimming or biodiversity.[74]

Because both choice experiment and contingent valuation methods are survey based methods, their application is very similar. The main differences are in the design of the valuation questions and the data analysis.[75] Again, great care needs to be taken in designing and implementing the survey. [76]

Benefit transfer method

The cost of valuing impacts on the environment can be considerable. However, it is not always necessary to undertake a new valuation study. Where valuation has been undertaken for a similar study elsewhere, it may be possible to transfer the estimates of value or the value functions derived from that study and employ them as indicators or approximations of value or value functions for the new study. This transfer of benefits derived from a previous study for use in a new study is called benefit transfer. The original valuation study may have utilised any of the valuation techniques outlined above.

Benefit transfer is undertaken for reasons of cost effectiveness and scope to rapidly inform decision-making. It is an attractive alternative to resource-intensive and time-consuming valuations based on original data (particularly stated preference methods). However, it is fraught with difficulties, related to the degree of similarity or dissimilarity between the site that was valued in the previous study (the study site) and the site that is to be valued (the policy site), the environmental goods and services being valued at the study site and the policy site, and the populations for the previous study and the new study.[77] An illustration of benefit transfer was the use of data from travel cost surveys of beach recreation use in other States of the United

[74] King and Mazzotta, n 72.
[75] King and Mazzotta, n 72.
[76] Adamowicz W, Louviere J and Swait J, *Introduction to Attribute-Based Stated Choice Methods* (Final Report to National Oceanic and Atmospheric Administration, January 1998) pp 12-16; see also Louviere J, Flynn T and Carson R, "Discrete Choice Experiments Are Not Conjoint Analysis" (2010) 3(3) Journal of Choice Modelling 57.
[77] Turner et al, n 40, p 77; Baker and Ruting, n 21, p 43.

States to estimate lost consumer surplus (loss of beach recreation benefits) caused by an oil spill on Californian beaches.[78]

Criteria for determining which studies are suitable for use in benefit transfer include:

(a) the environmental goods or services being valued should be the same;

(b) the relevant populations for whom environmental goods or services are to be valued should be very similar;

(c) the assignment of property rights for the environmental resources under consideration should be the same;

(d) the sites which provide the environmental goods or services should be similar;

(e) the quality of the previous study to be used for benefit transfer should be high.[79]

The benefit transfer method proceeds in four steps. The first step is to identify as precisely as possible the environmental outcome which may result from a proposed activity or resource allocation or management decision (such as a change in environmental quality). The nature of this expected change in environmental quality and its potential impact on the delivery of environmental goods and services will guide the research for similar studies that have already been undertaken elsewhere. Once the changes in environmental quality have been identified, the second step is to identify existing studies that have already been conducted on similar types of changes in environmental quality or that measure similar economic values, which can be used for the transfer. There are numerous environmental valuation databases that collect previous environmental valuation studies that can be used for benefit transfer.[80]

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[78] Chapman DJ, Hanemann WM and Ruud P, "The American Trader Oil Spill: A View From the Beaches" (Nov 1998) 18(2) Association of Environmental and Resource Economists Newsletter 12; Chapman DJ and Hanemann WM, "Environmental Damages in Court: The *American Trader* Case", in Heyes A (ed), *The Law and Economics of the Environment* (Edward Elgar, 2001) pp 319-367.
[79] Turner et al, n 40, p 77.
[80] See ENVALUE (a Searchable Environmental Valuation Database) available at: http://www.environment.nsw.gov.au/envalueapp/; EVRI (Environmental Valuation Reference

Once relevant studies have been identified, the third step is to decide whether the economic values derived in those studies can be reliably used and transferred to the policy site. The existing values or studies will be evaluated based on several criteria,[81] including:

(a) is the environmental good or service being valued comparable to the environmental good or service valued in the existing studies? Some factors that determine comparability are similar types of sites, similar quality of sites and similar availability of substitute sites; and

(b) are characteristics of the relevant population comparable? For example, are demographics similar between the area where the existing study was conducted and the area being valued? If not, is data available to make adjustments?

The fourth step is to proceed with the benefit transfer. Three broad approaches can be used for benefit transfer: unadjusted average value; adjusted average value; and value functions.[82] The first two approaches involve unit transfer – transfer of an available estimate of value of the change in environmental quality. The third approach involves function transfer – transfer of the function that yields the estimate of value.[83]

The first approach uses average value estimates without adjustments. This approach assumes the change in utility experienced by individuals considered in the new study is equivalent to that experienced on average by individuals in the previous study. For example, for a proposed activity or resource management decision that would affect recreational use benefits, the change in recreational services would be valued in terms of individuals' average willingness to pay per day. This could be estimated using values from suitable previous studies. The values from the study

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Inventory) available at: https://www.evri.ca/Global/HomeAnonymous.aspx; New Zealand Non-Market Valuation Database at: http://www2.lincoln.ac.nz/nonmarketvaluation/.

[81] King DM and Mazzotta MJ, "Benefit Transfer Method" at http://www.ecosystemvaluation.org/benefit_transfer.htm.

[82] Pearce DW, Whittington D and Georgiou S, *Project and Policy Appraisal: Integrating Economics and Environment* (OECD, 1994); Hanley, n 8, p 36.

[83] Baker and Ruting, n 21, p 30.

sites are transferred to and applied to the policy site. Multiplying the resultant figure by the predicted change in the number of person days of recreation in the new study would yield the total aggregate value of the anticipated impact on recreation.[84]

The second approach uses adjusted average value. This involves the adjustment of average values derived from previous studies of the study sites for any biases in the data that better reflect conditions examined in the new study of the policy site. For example, adjustments might be made to reflect the socioeconomic characteristics of households, such as income, the environmental change in question, the policy setting, or the availability of substitute or complementary goods or services. Such adjustments can increase the suitability of values for transfer to the policy site.[85]

The third approach uses value function. This entails transfer of the entire demand function or benefit function for the good or service in question to the new study. It enables transfer of more information than through use of average values alone. It is likely to result in better approximations of values, but is more involved that the other two approaches.[86]

Several limitations are common to all of these approaches: a requirement for high, quality studies of similar situations; the potential for characteristics to change between different time periods; and an inapplicability to the valuation of novel impacts.[87]

Discounting

Economic valuation monetises costs and benefits of human activities that impact on environmental quality or the flow of environmental goods and services. These costs and benefits may arise in different time periods. For example, the costs of taking action to mitigate greenhouse gas emissions may be incurred in the present but the benefits of the reduced risk of climate change and its consequences accrue over many decades, even centuries, into the future. However, decisions need to be made

[84] Turner et al, n 40, pp 77-78.
[85] Turner et al, n 40, p 78.
[86] Turner et al, n 40, p 78.
[87] Turner et al, n 40, p 78.

in the present as to whether the benefits of reduced risk of climate change outweigh, and therefore justify incurring, the costs of greenhouse gas mitigation. In order to do this, the cost and benefits over different time periods must be made commensurable. The recognised method of obtaining the present value at any moment in time is to weight the costs and benefits by a discount factor or rate (expressed as a percentage). This is done by discounting future costs and benefits back to a present value. The present value of a payment (of a cost or benefit) received "n" years in the future when the discount rate is "r" is given by the formula $PV = payment/(1 + r)^n$.

But what discount rate should be used? This depends on two factors: time preference and uncertainty in outcomes. The first is how we value a dollar in hand today over one in the future. The higher the discount rate, the more we value a dollar in hand today over one in the future. Insofar as economic costs and benefits are expressed as monetary values, this means that the higher the discount rate, the lower will be the future costs and benefits expressed in present value terms. For example, a discount rate of 10% makes the present value of the benefits of climate change prevention in 100 years from now much less than if the discount rate were to be 5%. The choice of the discount rate reflects, in part, an ethical choice: how much we value the wellbeing or utility of our generation over that of future generations is reflected in how much we value a dollar in the hand today over a dollar in the hand of future generations.

The second factor influencing the choice of discount rate is uncertainty in outcomes. For example, for a project that proposes restoration of the environment (perhaps to provide a biodiversity offset), there might be variance in the project benefits: the project may do better or worse than expected. Risk-adverse people generally prefer a lower average return. There may also be catastrophic failure: the project may fail due to internal events (eg poor design or implementation) or external events (eg natural or political events).[88]

[88] Hampton S and Zafonte M, "Discounting and Uncertainty in Natural Resource Damage Assessments" (Poster, Fourth World SETAC Congress, November 14-18, 2004, Portland, Oregon) available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=22080&inline=true.

The choice of discount rate can, therefore, be critical in order for action to improve environmental quality or to prevent a reduction in the environmental quality to pass the benefit-cost test.

There is general agreement as to what constitutes a reasonable range for the discount rate, but there are defensible arguments for choosing a rate within this range. The upper limit for the discount rate should be the average real long-term return on private investment. This discount rate forces environmental investments to earn a rate of return greater than or equal to the return of private investment in order to pass a benefit-cost test. People who propose this discount rate argue that environmental investments should compete with all other types of investments that society makes. If an environmental investment cannot match normal private rates of return, then society's resources would be better invested somewhere else.[89]

Others point out that the average return on private investment includes a premium for risk. If an environmental investment is very likely to yield positive social benefits, then the rate of return to pass the benefit-cost test should be lower than the average private return, which factors in this risk premium (or reward for taking the extra risk).[90] This would suggest that the rate of return on government bonds, which are guaranteed, may be more appropriate to use as a discount rate. Use of this discount rate would force environmental investments to earn a rate of return equal to or greater than the environmentally riskless option of government treasuries.[91]

For natural resource damage assessments in the United States under the *Comprehensive Environmental Response, Compensation and Liability Act* and *Oil Pollution Act*, a discount rate of 3% is used. This rate is slightly higher than the historical average of the real (inflation-adjusted), after-tax interest rate on 10-year United States Treasury notes, which is approximately 2%-3%.[92] The 3% discount

[89] Scorse J, *What Environmentalists Need to Know About Economics* (Palgrave-MacMillan, 2010) pp 45-46.
[90] Krutilla and Fisher, n 7, pp 63-64.
[91] Scorse, n 89, p 46.
[92] English EP, Peterson CH and Voss CM, "Ecology and Economics of Compensatory Restoration" (August 28, 2009) pp 157-158, available at http://www.mopt.org.pt/uploads/1/8/5/5/1855409/doc_english_ecology_and_economics_of_compensatory_restoration_2009.pdf.

rate used for natural resource damage assessments reflects only the social rate of time preference. It does not incorporate uncertainty. The risk and/or odds of failure of an environmental project could be incorporated directly into the discount rate.[93]

However, some people (including many environmentalists) argue that even a discount rate based on risk free interest rates for government treasury notes may be too high in certain circumstances. Many environmental resources are irreplaceable; once they are severely degraded or damaged, this damage cannot be reversed. The special nature of environmental resources might suggest that society should invest in saving them for future generations. Unlike a new road, school or factory, there may be no true substitute for a unique ecosystem, a stable climate, or an intact ozone layer. The more unique the environmental resource, the lower the discount rate should be.[94]

Lord Nicholas Stern in his review on the economics of climate change chose a very low discount rate to calculate the present value of the benefits of climate change mitigation for future generations.[95] Stern's discount rate had two components: a rate of pure time preference that would apply if all generations had equal incomes, and a growth-related rate, assuming that if future generations will be richer than the present generation, there is less need to make investments on their behalf today. Stern accepted the moral argument that present and future generations are of equal ethical standing, implying that the pure time preference rate should be zero. However, to avoid a technical issue, Stern introduced a miniscule rate of pure time preference, 0.1% per year, based on an arbitrary estimate of probability that the human race will not survive. Stern included a second component of his discount rate tied to economic growth. His discount rate thus became the rate of growth of per capita consumption, plus 0.1%. Since economic growth in his model averaged 1.3%, Stern's discount rate averaged 1.4%.[96] This led him to find that the future economic benefits of taking immediate action to limit greenhouse gas emissions outweighed the present costs of doing so.

[93] Hampton and Zafonte, n 88.
[94] Scorse, n 89, p 46.
[95] Stern N, *The Economics of Climate Change* (HM Treasury, 2006).
[96] Ackerman F, "The Stern Review vs its Critics: Which Side is Less Wrong?" (Economics for Equity and the Environment Network, 2009) available at: http://e3network.org/wp-content/uploads/2015/04/Ackerman_Stern_Review.pdf.

This very low discount rate was subject to criticism, although it was also supported by others.[97] If Lord Stern had selected a higher discount rate, even one in the low range of 2%-3%, the discounted future benefits of mitigating climate change might not have outweighed the present cost of doing so.

The choice of the discount rate from this range of discount rates that should be used in any particular economic valuation may depend on the nature of the environmental investment or the environmental outcome to be valued. A discount rate reflecting the market rate of interest may be appropriate when dealing with purely financial outcomes. However, a lower discount rate may be more appropriate for irreplaceable environmental goods or services.

Conclusion

Economics can provide tools by which to value the various goods and services that the environment provides that affect the wellbeing of individuals and society. By ascribing a monetary value to these goods and services, they are able to be compared and aggregated and set off against other monetary costs and benefits, and hence be taken into account in resource allocation and management decisions. Economic values may not capture all of the value of an environment, including the value of ecosystem functions and services that do not affect the utility of humans, or the intrinsic value of biotic components of the environment, but at least they provide some estimate of value – the value of the environment is at least as much as the total economic value. Economic valuation also does not assist in deciding issues of equity in the distribution of costs and benefits. Nevertheless, by facilitating the comparison and aggregation of costs and benefits, economic valuation assists in the integration of environmental considerations with economic considerations. Economic values are, therefore, important analytical tools that can assist decision-makers in making decisions about the wise use of the environment.

[97] See Ackerman F, "Debating Climate Economics: The Stern Review vs. Its Critics" (Report to Friends of the Earth England, Wales and Northern Ireland, July 2007) available at: https://www.foe.co.uk/sites/default/files/downloads/debate_climate_econs.pdf.