

Lecture note

Water resource economics

September 2005

by

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Lecture notes have been prepared on the following topics:

Aggregate water balances for basinwide planning

Case study: Kok River Basin

Case study: Lower Mekong Basin

Environmental management

Floods and drought

Glossary

Good governance strategies (example from Thailand)

Internet applications in river basin management

Paddy cultivation

Poverty alleviation

Project design

Public administration

Ramayana

Reporting

River basin ethics

River basin management

Sector planning and integrated planning

Socio-economics

Strategies for natural resources and environmental management (example from Thailand)

Technology management

UTM coordinates

Water demand management

Water resource economics

Water user associations

Each note is intended as a quick introduction of a subject prepared for professional practitioners who are specialists in other subjects.

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Suggestions and comments are most welcome!

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Glossary

Costs: Expenses incurred in connection with sales of products or services - procurement, production, storage, distribution and marketing etc.

Elasticity of demand: The change in demand in proportion to the change in price (price elasticity of demand); or the change in demand in proportion to the change in income (income elasticity of demand); or the change in demand in proportion to the change in price of a related good (cross elasticity of demand). Normally, the demand will go down when the price goes up

Elasticity of supply: The change in supply in proportion to the change in price (price elasticity of supply); or the change in supply in proportion to the change in income (income elasticity of supply); or the change in supply in proportion to the change in price of a related good (cross elasticity of supply). Normally, the supply will increase when the price goes up

Marginal costs: The change in total costs from changing the output by one unit

Marginal revenue: The change in total revenue from changing the output by one unit

Price elasticity for rice: In a poor country where most people spend a large part of their income to buy rice to eat, it can happen that a price increase for rice means that people have less money for supplementary food like meat and vegetables - so the demand of rice can go up instead of down. If the price of rice goes down, people can afford to buy more meat and vegetables - so the demand of rice can go down instead of up - as shown in the figure below

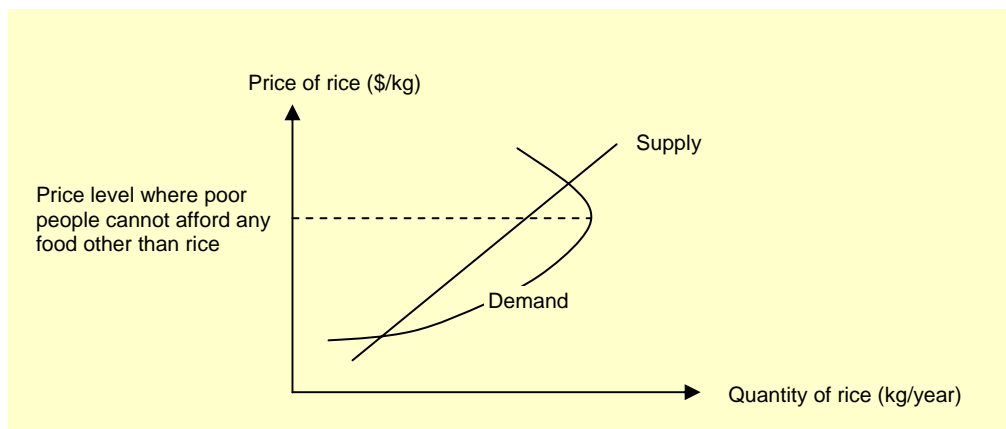


Figure from Hardwick et al (1990), p. 99

Production factor (or just 'factor'): An input to a production system, for example land, labour, capital, or water. **Factor endowment:** The (national) availability of a production factor

Profit: Total revenue minus total costs. The profit will be maximised at the output where the marginal costs equal the marginal revenue

Revenue: Income from sales of products or services - for example number of units multiplied by the sales price

Social Accounting Matrix (SAM): A table of all flows of money between actors and sectors, often describing one country and one year, used for analysis of income distribution

Subsidy: Public financial support to a sector, an industry or a supply of goods or services, in order to reduce the price (in the present context, in order to reduce the water fee)

Water fee: The price paid by the water user for the water - for example per m³, or per household, or per hectare. The fee equals the full supply costs minus a subsidy (if any) plus a tariff (if any)

Water tariff: A tax levied on water consumption for a purpose other than recovering the water supply costs - such as general public income generation, or in order to reduce the consumption

1 Introduction

Economic analysis is important and useful for decision-support in connection with investment, efficiency improvement and other management tasks.

If faced with a choice about how to reach a clear goal - be it a road between two towns, to be constructed and maintained for many years - or a new harbour, with an access channel that needs continuous maintenance dredging - an economic analysis can support the right decision. An economic analysis can even provide a part of the basis for selecting how to increase the average living-age of a country, or how to consolidate rural livelihoods.

In some cases, however, an economic analysis is not adequate for decision-making. It will not be able to indicate a choice between an investment in a new school or an investment in a new hospital. Or whether to decide on a beautiful but expensive new stadium, or a less beautiful but cheaper one. In these cases, the economic analysis can demonstrate the economic consequences of some decision, which is good and useful knowledge - but it cannot in itself identify the right choice.

In Southeast Asia, most economic analyses demonstrate that paddy cultivation is un-profitable. The farmers would earn more if they shifted to another occupation. Still, such knowledge is not adequate for decision-making. Other criteria than the economic ones must be considered: Food security (individual and national), rural livelihoods, and foreign currency earnings. The European Union, the US and Japan have decided, on a well-informed basis, to pay a much higher price for domestic food rather than imported food. Saudi Arabia is an exporter of wheat, even if this requires high subsidies.

Imagine that an economic analysis proves that some entire country is not profitable. What would you do with such knowledge?

2 Costs and benefits

2.1 *Cost-benefit analysis*

ADB (1997):

There are four basic steps to analyzing the economic viability of a project:

- identify the economic costs and benefits;
- quantify the costs and benefits, as much as possible;
- value the costs and benefits; and
- compare the benefits with the costs.

The first two steps can generally be undertaken together. However, there will be some types of benefits, and sometimes costs, that cannot be quantified and valued for inclusion in the cost-benefit comparison. They will simply be stated alongside the results of the economic analysis.

2.2 Financial versus economic analysis

A *financial analysis* addresses the implications to the enterprise; while an *economic analysis* addresses the implications to the society.

(According to ADB: *Guidelines for the Economic Analysis of Projects.*, 1997):

If the financial and economic boundaries of a project are the same, as in public utility projects for example, differences between financial and economic returns come down to differences between financial and economic prices.

The main differences between the economic and financial values of project costs and benefits are made up of government taxes and subsidies, excess operating surpluses from monopolized markets, foreign exchange premia, producer and consumer surplus, and positive and negative externalities. Economic values exceed financial values as a result of output taxes, input subsidies, foreign exchange premia, consumer surplus, and positive externalities. Financial values exceed economic values as a result of output subsidies, input taxes, foreign exchange discounts, producer surplus, and negative externalities.

A useful distinction can be made between financial internal rate of return (FIRR) and economic internal rate of return (EIRR); and between financial net present value (FNPV) and economic net present value (ENPV).

(According to Petrina Rowcroft June 2005):

Economic valuation requires that all values are expressed in terms of their opportunity costs to society.

Financial values

- Are accounting measures (direct account cash flows)
- Are usually expressed in nominal (ie constant price) terms

Economic values

- Reflect actual resource use (including opportunity costs of time, money and labour)
- Exclude transfers (e.g. taxes and subsidies) which are simply a reallocation of resources among groups in society, rather than an actual resource use
- Include externalities (unintended environmental and social impacts of a particular activity)
- Use real (present day) values to account for past/future cost-benefit streams

Example

An economic budget for a paddy farmer will describe the economics of the enterprise from the point of view of the society; while a financial budget will describe the economy from the point of view of the farmer. The financial budget will describe the earnings at the farmgate and the expenses actually paid by the farmer (for inputs, labour and land); while the economic budget will compensate for subsidies, indirect taxes, opportunity costs and externalities.

2.3 Internal rate of return (IRR)

The internal rate of return (IRR) is the estimated rate of return from an investment.

The investment is regarded as '*acceptable*' if the IRR is higher than the market rate of interest.

The IRR can be calculated by a formula like the following, after having established values and costs in terms of money:

$$\left[B_0 + \frac{B_1}{(1+i)} + \frac{B_2}{(1+i)^2} + \dots + \frac{B_t}{(1+i)^t} \right] - \left[C_0 + \frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \dots + \frac{C_t}{(1+i)^t} \right] = 0$$

where $B_0, B_1, B_2 \dots B_t$ are the benefits in years 0, 1, 2, ... t

$C_0, C_1, C_2, \dots C_t$ are the costs in years 0, 1, 2, ... t

i is the rate of interest

As compared with the net present value (NPV) (see below), the two tests are consistent as far as judging an investment as '*acceptable*' or '*not acceptable*': A positive IRR will also give a positive NPV, and a negative IRR will give a negative NPV. Regarding a choice between two acceptable alternatives, the two methods can give different results. The IRR will favour small investments with immediate returns, while the NPV will favour larger investments with more distant returns.

For public investments, the NPV is regarded as a more valid indication of the feasibility.

Issues and limitations are the same as for the NPV:

- 1 Re-distribution of income among stakeholders are not considered
- 2 Future benefits and costs are often difficult to predict
- 3 External benefits and costs (for example social and environmental benefits and costs) are often difficult to assess
- 4 The method is not suited for comparison of investments with different objectives - like either a university or an airport.

2.4 Marginal costs and revenue (of water supply)

The marginal costs of water supply are the costs of supplying one additional m³ of water to the consumers. The marginal costs can be capital costs (new wells or water intakes, expanded distribution network, expanded storage, expanded treatment capacity), and/or operation costs.

The marginal revenue is the revenue earned from (or value generated by) supplying one additional m³ of water to the consumers.

Costs and revenue can be considered as *financial* or *economic* (see Section 2.2), depending on whether the analysis is made in the perspective of the enterprise or in the perspective of the society as such. This distinction can be quite important.

In either perspective, it makes sense to increase the supply if the benefits exceed the costs.

In broad general, the marginal costs will increase with the production, while the marginal benefits will initially increase and then decrease, as shown below.

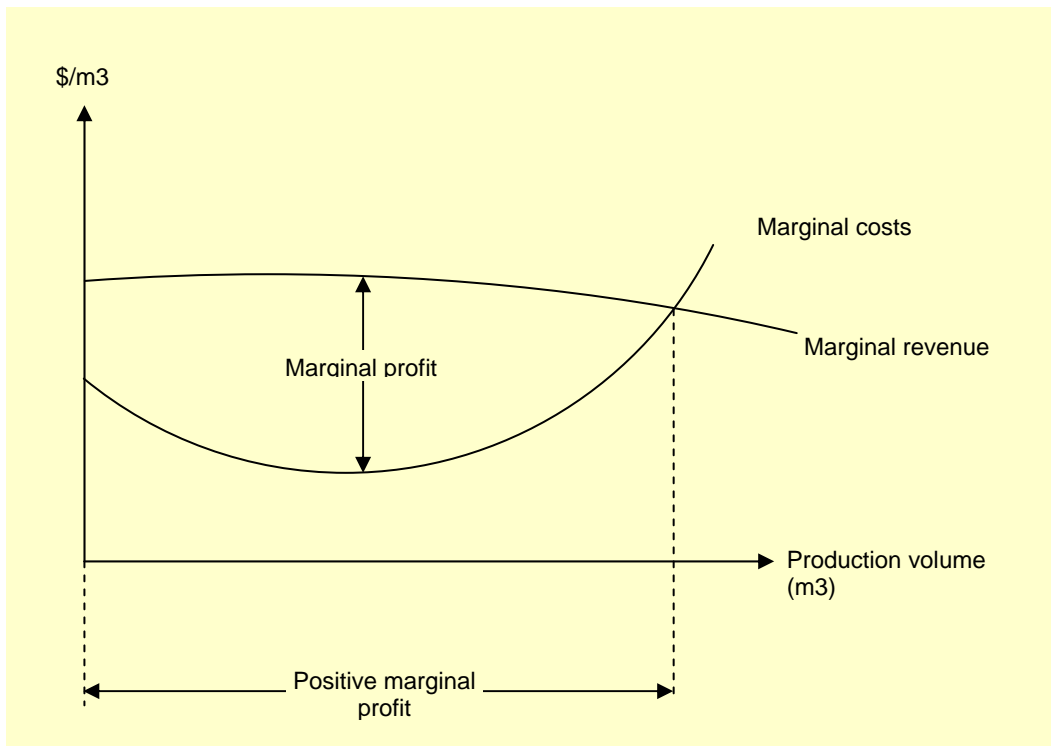


Figure 1: Marginal costs and marginal revenue

2.5 Net present value (NPV)

Net present value (NPV) is also called net discounted present value (NDPV).

According to ADB (1997), 'the NPV is the difference between the present value of the benefit stream and the present value of the cost stream for a project. The net present value calculated at the Banks discount rate should be greater than zero for a project to be acceptable'.

The NPV is calculated by

- (1) establishing values and costs in terms of money;
- (2) discounting future benefits and costs; and
- (3) subtracting the discounted costs from the discounted benefits:

$$NPV = \left[B_0 + \frac{B_1}{(1+i)} + \frac{B_2}{(1+i)^2} + \dots + \frac{B_t}{(1+i)^t} \right] - \left[C_0 + \frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \dots + \frac{C_t}{(1+i)^t} \right]$$

where $B_0, B_1, B_2 \dots B_t$ are the benefits in years 0, 1, 2, ... t

$C_0, C_1, C_2, \dots C_t$ are the costs in years 0, 1, 2, ... t

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As compared with the internal rate of return (IRR) (see Section 2.3 above), the two tests are consistent as far as judging an investment as '*acceptable*' or '*not acceptable*': A positive NPV will also give a positive IRR, and a negative NPV will give a negative IRR. Regarding a choice between two acceptable alternatives, the two methods can give different results. The IRR will favour small investments with immediate returns, while the NPV will favour larger investments with more distant returns.

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2.6 Opportunity costs

Opportunity costs are the cost difference between one course of action and another (better or '*best*') course of action.

In a wider sense: The implications of one course of action relative to alternative strategies.

In development projects, the opportunity costs can reflect the time lag from when a new technology emerges and until it becomes available to the target group.

There is often an opportunity cost related to doing nothing

2.7 Total Economic Value (TEV)

(after Pearce and Moran 1994)

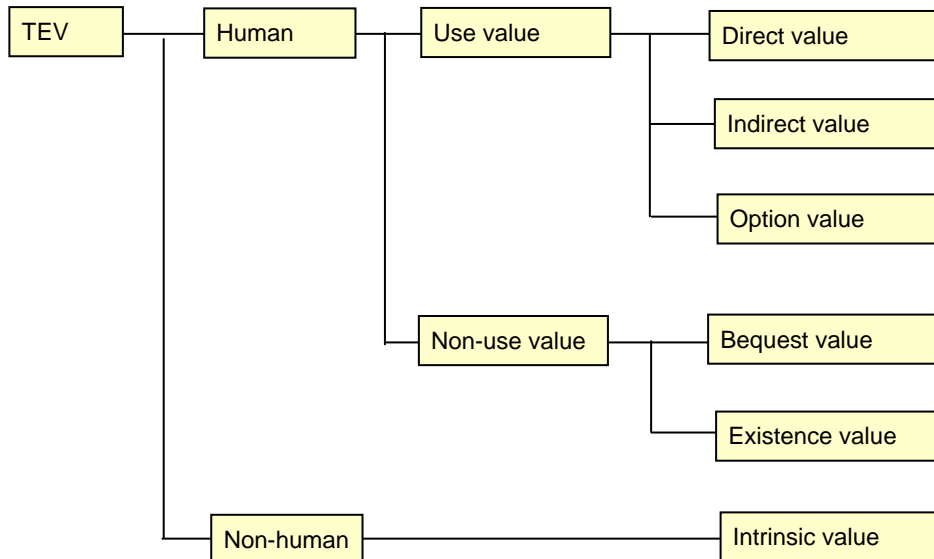


Figure 2: Total Economic Value

Direct value is related to production and consumption of goods (primary & secondary) that can usually be traded (so the value becomes visible). Examples: Crops, fish, firewood, water, electricity

Indirect value is the benefits derived from ecosystem functions. These are usually not traded - so the value becomes uncertain - but can be large. Examples: Flood control, storm protection, soil conservation; value related to income from tourism

Option value is the value derived from a possible future use. Example: A groundwater resource, a hydropower potential

Bequest value is the value of conserving things for future generations. Example: A fish or forest resource or a waterfall

Existence value is related to the satisfaction to know that something exists - such as cultural value, heritage value, spiritual value, etc.

Intrinsic value is the value of a living resource in its own right, unrelated to human utilization. Example: The Mekong giant catfish; etc.

2.8 Sensitivity analysis

A sensitivity analysis describes how sensitive a result is to the assumptions made.

For example, in connection with a cost benefit analysis, supplementary, parallel analyses can be made based on '*optimistic*' and '*pessimistic*' assumptions.

A sensitivity analysis can identify critical assumptions (like future labour or energy costs, or a rate of interest) and can describe a realistic interval of the achievable benefits and costs of an investment, rather than a single value.

ADB (1997):

Sensitivity analysis. The analysis of the possible effects of adverse changes on a project. Values of key variables are changed one at a time, or in combinations, to assess the extent to which the overall project result, measured by the economic net present value, would be affected. Where the project is shown to be sensitive to the value of a variable that is uncertain, that is, where relatively small and likely changes in a variable affect the overall project result, mitigating actions at the project, sector, or national level should be considered, or a pilot project implemented

3 Valuation methods

3.1 Water valuation

The direct value to users of water can be expressed in terms of crop yield, production output, generated energy, environmental quality, or money, expressed per unit of water, or as a function of quantity. The total value of water is

- the direct value, plus
- net benefits of return flows,
- net benefits from indirect uses,
- a societal value, and
- an intrinsic¹ value (reflecting access, ownership, amenity², etc).

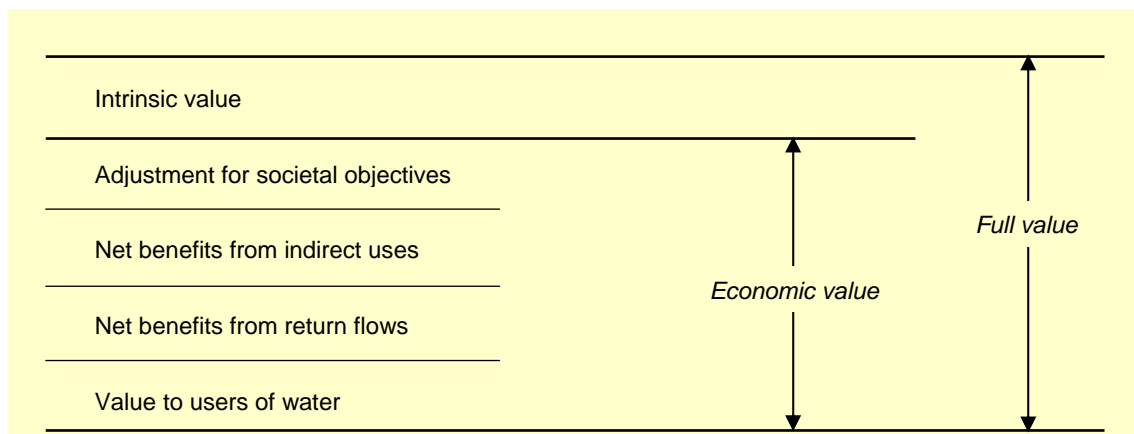


Figure 3: Full value of water (GWP March 2000, p. 19)

The cost of water can be divided into

- operation and maintenance costs of supply and distribution system;
- capital costs;
- opportunity costs;
- external costs; and
- environmental costs.

(External costs are consequential costs or benefits, or simply opportunity costs in a wider sense).

¹ Intrinsic value = 'value in its own right, unrelated to its use'

² Amenity = attractiveness (of a water body / water resource)

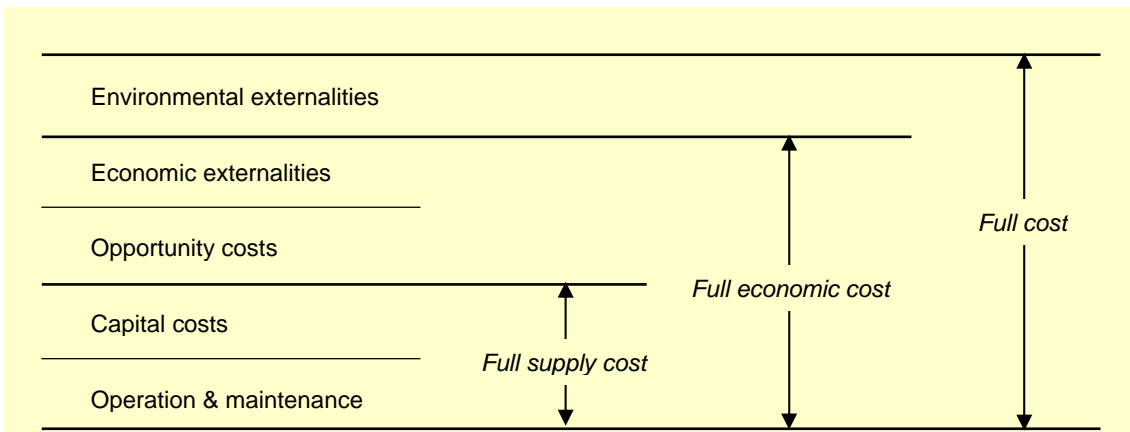


Figure 4: Water costing (GWP March 2000, p. 20)

3.2 Benefit transfer method (BTM)

(After Dennis M. King and Marisa Mazzotta, <http://www.ecosystemvaluation.org/>)

The benefit transfer method is used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context.

Thus, the basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context. Benefit transfer is often used when it is too expensive and/or there is too little time available to conduct an original valuation study, yet some measure of benefits is needed. It is important to note that benefit transfers can only be as accurate as the initial study.

Advantages

- Benefit transfer is typically less costly than conducting an original valuation study.
- Economic benefits can be estimated more quickly than when undertaking an original valuation study.
- The method can be used as a screening technique to determine if a more detailed, original valuation study should be conducted.
- The method can easily and quickly be applied for making gross estimates of recreational values. The more similar the sites and the recreational experiences, the fewer biases will result.

Issues and limitations

- Benefit transfer may not be accurate, except for gross estimates, unless the sites share all of the site, location, and user specific characteristics.
- Good studies for the policy or issue in question may not be available. Even if they exist, the reporting of existing studies may be inadequate to make the needed adjustments.
- Extrapolation beyond the range of characteristics of the initial study is not recommended.
- Benefit transfers can only be as accurate as the initial value estimate.
- Unit value estimates can quickly become outdated.

3.3 Damage cost avoided/ replacement cost methods

(After Dennis M. King and Marisa Mazzotta, <http://www.ecosystemvaluation.org/>)

The damage cost avoided, replacement cost, and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing environmental assets, or the cost of providing substitute services.

The damage cost avoided method uses either the value of property protected, or the cost of actions taken to avoid damages, as a measure of the benefits provided by an ecosystem. For example, flood protection benefits may be estimated by the damages avoided if the flooding is prevented.

The replacement cost method uses the cost of replacing an ecosystem or its services as an estimate of the value of the ecosystem or its services. Similarly, the substitute cost method uses the cost of providing substitutes for an ecosystem or its services as an estimate of the value of the ecosystem or its services.

Because these methods are based on using costs to estimate benefits, it is important to note that they do not provide a technically correct measure of economic value, which is properly measured by the maximum amount of money or other goods that a person is willing to give up to have a particular good, less the actual cost of the good. Instead, they assume that the costs of avoiding damages or replacing natural assets or their services provide useful estimates of the value of these assets or services.

The methods may provide a rough indicator of economic value, subject to data constraints and the degree of similarity or substitutability between related goods.

Advantages

- It is easier to measure the costs of producing benefits than the benefits themselves, when goods, services, and benefits are non-marketed. Thus, these approaches are less data- and resource-intensive.
- Data or resource limitations may rule out valuation methods that estimate willingness to pay.

- The methods provide indicative estimates for services which may be difficult to value by other means.

Issues and limitations

- These approaches assume that expenditures to repair damages or to replace ecosystem services are valid measures of the benefits provided. However, costs are usually not an accurate measure of benefits.
- The goods or services being replaced probably represent only a portion of the full range of services provided by the natural resource. Thus, the benefits of an action to protect or restore the ecological resource would be understated.

3.4 Market price method

(After Dennis M. King and Marisa Mazzotta, <http://www.ecosystemvaluation.org/>)

The market price method estimates the economic value of ecosystem products or services that are bought and sold in commercial markets. 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, 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 resources traded in the marketplace 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.

The market price method uses prevailing prices for goods and services traded in markets, such as timber or fish sold commercially. Market price represents the value of an additional unit of that good or service, assuming the good is sold through a perfectly competitive market (that is, a market where there is full information, identical products being sold and no taxes or subsidies).

Advantages

- The market price method reflects an individual's willingness to pay for costs and benefits of goods that are bought and sold in markets, such as fish, timber, or fuel wood. Thus, people's values are likely to be well-defined.
- Price, quantity and cost data are relatively easy to obtain for established markets.
- The method uses observed data of actual consumer preferences and standard, accepted economic techniques.

Issues and limitations

- Market data may only be available for a limited number of goods and services provided by an ecological resource and may not reflect the value of all productive uses of a resource.

- The true economic value of goods or services may not be fully reflected in market transactions, due to market imperfections and/or policy failures.
- Seasonal variations and other effects on price must be considered.
- The method cannot be easily used to measure the value of larger scale changes that are likely to affect the supply of or demand for a good or service.
- Usually, the market price method does not deduct the market value of other resources used to bring ecosystem products to market, and thus may overstate benefits.

3.5 Productivity method

(After Dennis M. King and Marisa Mazzotta, <http://www.ecosystemvaluation.org/>)

The productivity method, also referred to as the net factor income or derived value method, is used to estimate the economic value of ecosystem products or services that contribute to the production of commercially marketed goods. It is applied in cases where the products or services of an ecosystem are used, along with other inputs, to produce a marketed good.

For example, water quality affects the productivity of irrigated agricultural crops, or the costs of purifying municipal drinking water. Thus, 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.

If a natural resource is a factor of production, then changes in the quantity or quality of the resource will result in changes in production costs, and/or productivity of other inputs. This in turn may affect the price and/or quantity supplied of the final good. It may also affect the economic returns to other inputs.

To apply the productivity method, data must be collected regarding how changes in the quantity or quality of the natural resource affect:

- costs of production for the final good
- supply and demand for the final good
- supply and demand for other factors of production

This information is used to link the effects of changes in the quantity or quality of the resource to changes in consumer surplus and/or producer surplus, and thus to estimate the economic benefits.

Advantages

- In general, the methodology is straightforward.
- Data requirements are limited, and the relevant data may be readily available, so the method can be relatively inexpensive to apply.

Issues and limitations

- The method is limited to valuing those resources that can be used as inputs in production of marketed goods. When valuing an ecosystem, not all services will be related to the production of marketed goods. Thus, the inferred value of that ecosystem may understate its true value to society.
- If the changes in the natural resource affect the market price of the final good, or the prices of any other production inputs, the method becomes much more complicated and difficult to apply.

3.6 Willingness to pay (WTP)

(After Dennis M. King and Marisa Mazzotta, <http://www.ecosystemvaluation.org/>)

Willingness to pay is a set of valuation methods that relate the value of a resource (like water or electricity) to what people are willing to pay for it.

There are two basically different ways of doing this:

- (1) By observation of people's actual behaviour (or '*revealed preferences*') (for example by establishing the observed demand function for a resource) (like water or electricity);
- (2) by simply asking people about what they are willing to pay for some resource (or their '*stated preferences*').

For example, 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, contingent on a specific hypothetical scenario and description of the environmental service.

The contingent valuation method is the most widely accepted method for estimating total economic value, including all types of non-use, or '*passive use*' values. The method can estimate use values, as well as existence values, option values, and bequest values. Results are often regarded as highly uncertain, however.

4 Miscellaneous

4.1 Demand management

Water demand management is a tool for achieving harmony between the demand of water and the availability of water.

If water (or money) is limited, such management can be required in support of important water-related development goals: (i) Economic development; (ii) food security; (iii) poverty alleviation in towns and in rural areas; (iv) rural livelihood consolidation and development; and (v) environmental protection.

The demand of *water for domestic consumption* can be controlled by measures such as

- installation of water meters, and charging a water fee;
- applying different tariffs for different housing areas;
- generation of awareness about prudent use of water;
- rationing of water (normally in case of critical shortage only).

The demand of *water for industrial consumption* can be controlled by measures such as

- installation of water meters (if not done already), and charging a water fee;
- applying different tariffs for different users and different seasons;
- promotion of new, water-efficient technology; and/or
- rationing of water (normally in case of critical shortage only).

The demand of *water for irrigation* can be controlled by measures such as

- charging a water fee that depends on the volume of water used (rather than the irrigated area);
- applying different tariffs for different seasons;
- generation of awareness about prudent use of water;
- promotion of good operation and maintenance;
- promotion of new, water-efficient technology (crops and cultivation routines); and/or
- rationing of water, possibly by de-central administration (water user groups).

Advantages of demand management are:

- Low investment required
- Public income can be generated by water fees
- Incentive to industries and agriculture to improve their efficiency (and thereby their competitiveness in an open market)
- Raw water is preserved for alternative uses downstream, including fisheries
- Less pollution generated, less sewage treatment capacity required

Disadvantages of demand management are:

- Excessive demand management can affect general economic development
- Risk of adverse social impact to the poor part of the population
- The negative effects of demand management will be less if regulation is introduced gradually, by small steps, and in a transparent and predictable way.

4.2 Pareto-optimization

(After Vilfredo Pareto, Italian economist, 1848-1927):

An optimal solution is:

- (1) A solution with 'absence of a distributable surplus' (Maurice Allais 1943); or
- (2) a state where nobody can be made better off without someone being made worse off.

In planning, it is normal that there is a whole profile of optimal solutions, from low-value-and-low-cost solutions to high-value-and-high-cost solutions. In river basin planning, a solution that is optimal for a sub-basin can be sub-optimal for the entire basin.

A sub-optimal (or inferior or deficient) solution is:

- (1) A solution with an unallocated surplus; or
- (2) a solution where the value can be increased without increasing the costs, and/or where the costs can be reduced without reducing the value

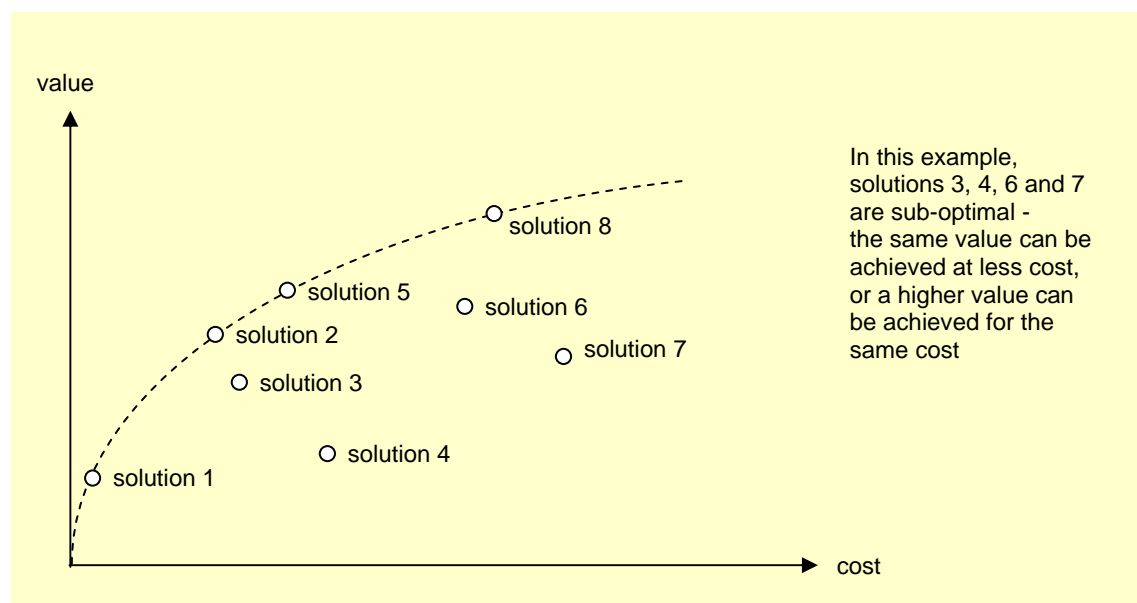


Figure 5: Pareto optimization

4.3 Scenario analysis

Scenario: A possible future situation, which is the result of a (hypothetical) combination of events, developments and conditions.

For example, a scenario can reflect

- *'business as usual'* (= no intervention);
- accelerated technological development;
- low and high development of irrigation systems;
- a series of dry years; and/or
- alternative modes of demand regulation and other intervention in water availability and water demands.

Scenario analysis is used to assess the development effects of costs, demand, competition and other aspects, in support of feasibility analyses or strategic planning.

A distinction (suggested by MRC-WUP-A, 2003) may be made between

- a *'planning scenario'* of circumstances outside the control of the planning (climate, energy prices, population growth), and
- a *'development scenario'* of such circumstances + the related demand (of water) + interventions to meet this demand.

This would comprise *'a unique combination of hydrological circumstances, demands, and interventions to try to meet those demands'*.

A scenario analysis can illustrate the significance of *'driving forces'* - which are circumstances with a major (positive or negative) influence on the development. They can be physical, climatic, economic, or political, and can appear as a trend, a cycle, or an event. A driving force cannot be controlled. It can be unpredictable, or not well understood, or even unknown.

4.4 Subsidies

A subsidy is a public financial support to a sector, an industry or a supply of goods or services, in order to reduce the price.

ADB (1997):

In the provision of utility services, a subsidy is the difference between average user charges and the average incremental cost of supply. A subsidy can be estimated in economic terms, using economic costs of supply, or in financial terms using financial costs of supply. The economic effects of a subsidy include the consequences of meeting them through generating funds elsewhere in the economy. Subsidies need explicit justification on efficiency grounds, or to ensure access to a selected number of basic goods.

4.5 Water tariffs / green taxes

When a tariff is introduced (or, perhaps, later on, increased), the consumption will go down. This is a general consumer habit phenomenon - it relates to many goods and services - for example telephone, electricity, buses, trains, taxis, gasoline, pesticides, fertilisers, cigarettes, beer - and water.

Water tariffs can have several purposes: Cost recovery; and/or (public) income generation; and/or demand regulation. A tariff can be flat or progressive. It can distinguish between different uses of water (domestic, industry, etc); different seasons; and/or different income groups.

A tariff that aims at reducing the consumption is sometimes called a *green tax*. Such tariffs (or taxes) are levied in order to regulate consumption, production or behaviour that affects pollution or utilisation of sparse resources. They aim at a better concordance between

- actual, immediate, direct (market) costs; and
- total, long-term social costs (including public health, environmental impact and preservation of important resources)

Green taxes can serve a fiscal purpose as well - or they can be fiscally neutral, if the income from the taxes is used for subsidies of the same sector.

The effect of a water tariff depends on the price elasticity, as shown in the figure below.

The opposite of a tariff is a subsidy. A subsidy is applied when the costs are not recovered from the users, but are (wholly or partly) covered by somebody else - for example other taxpayers - *the costs are there in any case, whether or not they are recovered*. While a tariff in general will reduce the consumption, a subsidy will in general increase the consumption.

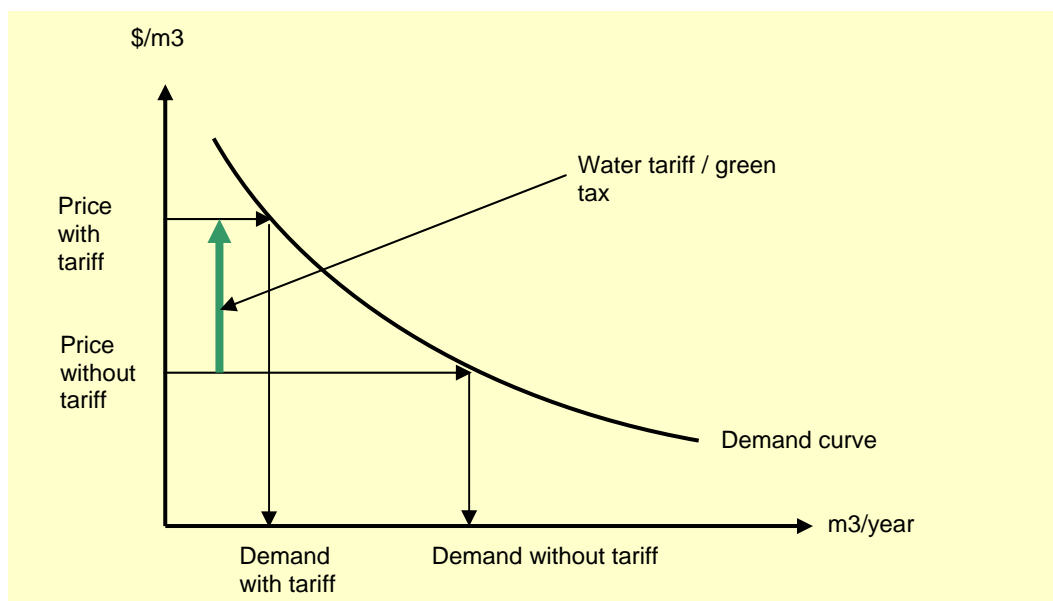


Figure 6: Effect of a water tariff

The following aspects relate to water fees, tariffs and subsidies:

- A tariff generates public revenue, while a subsidy is a public expense.
- The full costs of water supply need to be covered in the end, somehow - either by the water users or by somebody else
- If the water supply utilities are not self-sustaining, there is a risk that maintenance is downgraded, which can, in turn, increase the total maintenance costs (if a small repair in time can prevent the need of a comprehensive restoration later on)
- A low price of water can encourage waste, while a high price can encourage savings and efficiency improvements
- High subsidies can benefit the big users rather than the small ones, so there is a risk of adverse social distortion

4.6 Virtual water

Introduced by Tony Allan 1993, see Allan (March 03)

Quoted from <http://www.waterfootprint.org/>

The virtual water content of a product is the volume of water used to produce the product, measured at the place where the product was actually produced. The adjective 'virtual' refers to the fact that most of the water used to produce a product is in the end not contained in the product. The real water content of products is generally negligible if compared to the virtual water content.

The virtual water export of a country or region is the volume of virtual water associated with the export of goods or services from the country or region.

The virtual water import of a country or region is the volume of virtual water associated with the import of goods or services into the country or region. Viewed from the perspective of the importing country, this water can be seen as an additional source of water that comes on top of the domestically available water resources.

4.7 Water footprint

Introduced by Arjen Hoekstra, see Hoekstra and Hung (Sep 2002),

Quoted from <http://www.waterfootprint.org/>

The water footprint of an individual, business or nation is defined as the total volume of fresh water that is used to produce the foods and services consumed by the individual, business or nation. A water footprint is generally expressed in terms of the volume of water use per year.

Examples

- The production of one kilogram of beef requires 16 m³ of water.
- The production of one kilogram of milled rice (in Southeast Asia) requires 3-6 m³ of water.
- To produce one cup of coffee we need 140 litres of water.
- One bottle of beer (33 cl) requires 99 litres of water
- The water footprint of China is about 700 m³ per year per capita. Only about 7% of the Chinese water footprint falls outside China.
- Japan, with a footprint of 1,150 m³ per year per capita, has about 65% of its total water footprint outside the borders of the country.
- The USA water footprint is 2,500 m³ per year per capita.

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