Water management and development

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Water resource scarcity is one of the most pervasive natural resource allocation problems facing development planners throughout the world. Water resource scarcity can be a result of decrease water quantity following growing demand, or decreased quality resulting from degradation of freshwater resources, or both. By 2025, it is expected that the number of countries qualifying as 'water-scarce' will have increased to 35 from 20 in 1990 (UNEP 2003). To illustrate the magnitude of the problem, it has been estimated that, globally, 12 million deaths can be attributed to water scarcity in any given year (Shaw 2005). Water scarcity is widely perceived to be an important con- straint on sustainable economic development, and has major environmental, social, economic and political repercussions. Furthermore, sustainable economic development, especially for developing countries, is threatened by flood events, stressing even more the need for appropriate policies for water resources management.

In this chapter, the market and government failures that affect water management are highlighted. We then provide a summary of valuation methods for water resources, and a typology of economic instruments considered and applied in providing incentives for the rationalization of common resources like surface and groundwater. Then we outline a methodology for integrated water resources management compatible with the goals of economic efficiency, equity and environmental sustainability. This emphasizes the importance of using declining social discount rates (DDR) for environmental management, and is illustrated by providing an example of flood-control investment in developing countries.

Market failures in water resources management and optimal use

Market and government failures

Water services are public goods, and a market failure will result in the misallocation of resources. Furthermore, some water services are characterized by economies of scale, resulting in monopolistic power and socially inefficient allocations. When considering groundwater resources, three externalities can be distinguished:

- the finite stock of groundwater resources implies that each unit of groundwater extracted is no longer available for others to use, therefore there is little incentive to save water for future use, which in turn leads to overpumping. Provencher and Burt (1993) call this the stock externality.
- In addition, there is a pumping cost externality: as the water table declines with increasing extraction, the pumping cost to the firm increases, as do the pumping costs of the other firms exploiting the resource. Since a firm does not take the other firms' costs into account, a second externality is generated.
- Finally, there is the risk externality, which is caused by the inherent value of groundwater as a substitute source of water in times of surface water shortages.

Decreases in surface and groundwater quality are a result of environmental externalities in production. In these cases, the social costs of producing a good are ignored, leading to artificially low production costs and, hence, overproduction of the good that generates the externality. This situation is often enhanced by government failures that lead to misallocation of water resources. A key example is subsidies to agricultural production leading to over-exploitation of water resources for irrigation.

Optimal allocation of scarce water resources

As a result of the above failures, water supply and demand imbalances frequently occur, and water is not allocated efficiently among the resource users. Additionally, there are spatial and temporal considerations that need to be taken into account when valuing water, and these vary according to quality and its use, thus making water a more challenging resource to manage efficiently. In order to attain allocative efficiency, the marginal value of water should be the same for the last unit of water consumed by each water user, and should be equal to the social marginal cost of supplying water. For this to be achieved it is necessary that policymakers can properly value the water resource and then apply the appropriate policy instruments.

Non-market valuation techniques

In part, as a result of these market and government failures, degradation and loss of the environmental functions of water resources were prolific in the twentieth century. However, due to the observed loss of many ecological and hydrological services formerly provided (for free) by aquatic systems, and the consequent environmental and economic costs of this loss, aquatic system protection and conservation has become an internationally important political issue.

In economics, the basis of value is determined by individual preferences. Preferences reflect the utilities that are expected to be derived from the consumption of resources, given the needs, wants and wishes of consumers. In order to evaluate a given resource correctly, one needs to consider the *total economic value* (TEV) of the resource, that is, the whole class of values that have a basis in human preferences. Total economic value is composed of direct and indirect use values, as well as non-use values. Current use value derives from the utility gained by an individual from the consumption of a good or service, or from the consumption of others. *Current-use value* is composed of direct-use value (commercial and recreational) and indirect-use value (such as amenity value or general ecosystem support). *Option value* derives from retaining an option to a good or service for which future demand is uncertain. If we are not certain about either our future preferences or future availability, we may be willing to pay a premium (the option value) to keep the option of future use open. *Existence value* is derived from human preferences for the existence of resources as such and is unrelated to any use to which such resources may be put. Individual preferences may exist for maintaining resources in their present forms even where no actual or future 'use' is expected to be made of the resource.

Given that many of these components of value are not reflected in market prices of water, economists will attempt to estimate the true resource value through user *willingness to pay* for a given quantity and quality of supply. Valuation techniques are therefore necessary to assign appropriate prices that will enable water to be allocated in the most efficient manner. A variety of these techniques have been developed over the years to address this issue and are generally classified as revealed preference techniques and stated preference techniques. A comprehensive, state-of-the-art review of valuation techniques and relevant empirical applications from Europe and the rest of the world can be found in Koundouri 2004. Revealed preference techniques use data on goods or services that are marketed and do have observable prices, in order to value some environmental attribute, which is embodied in the marketed goods and services, but is not traded itself in any particular market.

Prominent revealed preference methods are the *residual value* method, the *hedonic pricing* method and the *travel cost* method. The residual value method values all inputs for the good produced at market price, except for the water resource itself. The residual value of the good is attributed to the water input. For example, one can value water as an input in the production of different crops. With the hedonic pricing method, the implicit prices of the characteristics that differentiate closely related goods can be estimated (Koundouri and Pashardes 2003). Travel cost models (also known as recreation demand models) represent an alternative revealed preference technique, which focuses on choice of trips or visits for recreational purposes, and looks at the level of satisfaction, time and money spent in relation to the activity. Patterns of travel to a particular site can be used to analyse how individuals value the site and, for example, the water quality of a river stretch.

In stated preference techniques, individuals are provided with a scenario in which they are asked how much they are willing to pay for changes in environmental quantity. The most widely applied stated preference method is the *contingent valuation* (Birol et al. forthcoming 2007), while valuation practitioners are increasingly interested in alternative stated preference formats, such as *choice modelling* (Hanley, Mourato and Wright 2001). Choice modelling is a family of survey-based methodologies (including choice experiments, contingent ranking, contingent rating and paired comparisons) for modelling preferences for goods, which can be described in terms of their attributes and levels they take (Birol and Koundouri 2006; Birol et al. forthcoming 2007).

Recent years have seen a growing interest in the application of meta-analysis for the estimation of use and non-use values generated by environmental resources. Meta-analysis is the statistical analysis of the summary of findings of empirical studies, that is, the statistical analysis of a large collection of results from individual studies for the purpose of integrating the findings. Brouwer et al. (2004) present such a meta-analysis for the use and non-use values generated by wetlands across Europe and North America.

Each of the valuation methods has advantages and disadvantages, and the appropriate method depends on the components of economic value one is trying to estimate. Once realistic estimates of surface and groundwater values are available, it is then necessary for governments to determine which policy measures are most suitable to achieve the desired outcomes.

Economic instruments for efficient surface and groundwater management

A number of economic instruments have been proposed for the efficient management of surface and groundwater resources (Karousakis and Koundouri 2006). In this section, a short description of the most common instruments is provided, and Table 1 summarizes the economic instruments proposed and their respective advantages and disadvantages.

Legal standards or quotas can be imposed to place restrictions on the quantity of water that can be extracted. Standards and quotas may also be used to prevent the deterioration of water quality below a certain level. An objection to the application of legal standards and quotas stems from the fact that they do not improve economic efficiency and, as such, they do not strictly qualify as economic instruments.

Taxes can be used to restrain water users from over-exploiting a water resource. The efficiency of taxes will depend on technical and institutional factors, while their effectiveness relies on the correct estimation of the marginal tax level and the risk aversion of farmers towards reduced water availability. Water pollution taxes can also be used to address water quality issues, when adopted to their optimal level.

Direct or indirect subsidies can provide incentives for water-saving measures. However, they are not economically efficient since they create distortions and provide counter-incentives for the adoption of new, environmentally friendly technologies.

In order to achieve efficient allocation of water resources, the creation of water markets, through the introduction of property rights to the common resource via tradable permit schemes, may be applied. The rationale behind tradable permit schemes is that in a competitive market, permits will flow to their higher value use. Their financial impact and their acceptability will be dependent on the initial allocation of property rights.

To minimize tensions between the stakeholders to the common water resource, voluntary agreements between farmers and government organizations can be implemented. Thus, efficiency is achieved since the agreements rely on the specialized knowledge of the agents directly concerned.

Environmental liability systems intend to internalize and recover the costs of environmental damage through legal action and to make polluters pay for the damage their pollution causes. If the penalties are sufficiently high, and enforcement is effective, liability for damage can provide incentives for taking preventative measures.

Table 1 Classification of economic instruments

Economic instrument	*Advantages*	*Disadvantages*
1. Standards and quotas		Not economically efficient
2. Water abstraction charges	Adjustment of price signals to reflect actual resource costs; encourage new technologies; flexibility; generation of revenues	Low charges will have minimal impact on user behaviour and will continue in resource overutilization
3. Pollution charges	Same as water abstraction charges; polluter-pays principle	Same as water abstraction charges
4. Subsidies	Readily acceptable	Not economically efficient
5. Tradable permits	Quantity-based targets that are able to attain least-cost outcome; allows flexibility	May entail high transaction costs
6. Voluntary agreements	Readily acceptable	
7. Liability legislation	Assess and recover damages *ex post*, but can also act as prevention incentives	Require an advanced legal system; high control costs; burden of proof

A methodology for implementing integrated water management in developing countries

Below, the problem of water resource allocation at the watershed level is addressed by providing a suggested methodology for integrated water management. The methodology can be seen in terms of two complementary stages, the first consisting of an objective approach to ascertaining economically efficient water allocations, and the second consisting of policy impact analysis. This two-stage methodology aims to present policymakers and resource managers with a procedure suitable to attain economic efficiency while simultaneously being compatible with the goals of equity and environmental sustainability.

In the first stage, water demands should be evaluated in order to derive the policy-relevant parameters, such as the *marginal value of water*, *price elasticities of demand*, *income elasticity of demand*, *marginal willingness to pay* and *risk parameters* for all relevant dimensions of demand. Then the economically efficient allocations – defined as those allocations where the *marginal social benefit* from consuming water is equated to the *marginal social cost* of supplying it – ought to be identified. As the last step in this stage, the impacts of implementing the efficient allocations should be ascertained. This involves the identification of the impacts on society from applying economic instruments to implement the efficient allocation, thus leading to the second stage of the methodology.

In the second stage, a full policy impact analysis should be conducted. At first, the impact of the allocation of policy options on welfare needs to be evaluated and the distribution of costs and benefits to the society established. Next, possible externalities and market failures that may arise from the chosen allocation will have to be addressed, since ignoring them may lead eventually to suboptimal allocations. This is probable in cases where users are linked by the underlying hydrology of the aquifer. Overall, policymakers will consider the sectoral, spatial and temporal allocations. Finally, institutional and legislative analysis may be required in order to facilitate reallocation of water resources.

The issue of long-run discounting

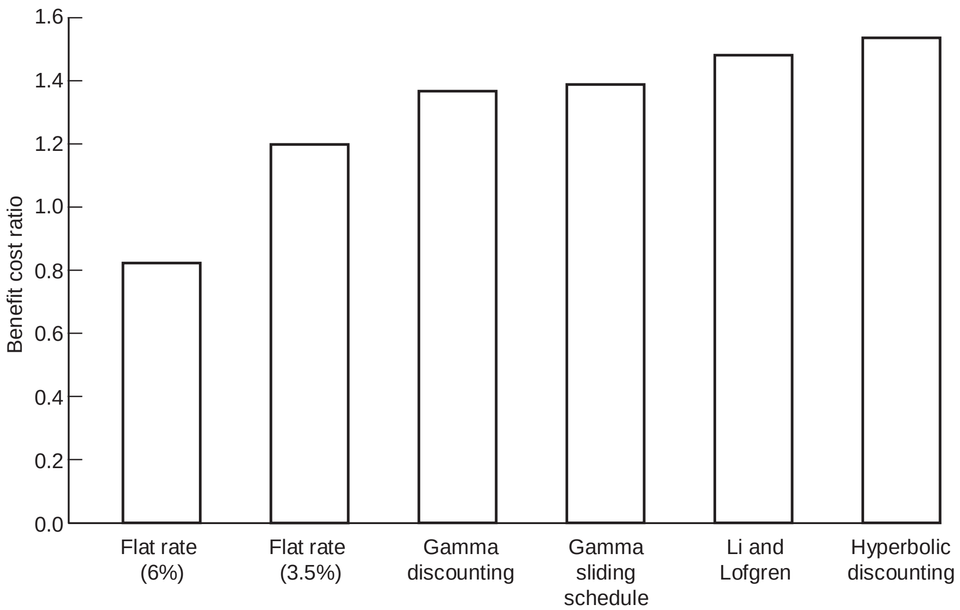
The efficiency of a public investment project is determined by *social cos- benefit analysis*, where the total social benefit of the project is compared to its total social cost. In a competitive economy, the socially efficient level of investment is attained by investing in projects where the net present value determined by discounting cost and benefits at the *social discount rate* is positive. Then, the level of social discount rate is crucial in determining whether a public investment will pass the cost-benefit analysis test.

Discounting at a constant positive rate for policies seeking solutions to long-term environmental problems is considered problematic, since the net benefits accruing to generations in the distant future appear relatively negligible. Furthermore, constant discounting appears contrary to sustainable development.

In order to face these issues, the use of a discount rate that declines over time, following a predetermined trajectory (DDR) has been proposed (see, for example, Cropper, Ayded and Portney 1994, Cropper and Laibson 1999, providing experimental evidence revealing that people discount the future at declining rates roughly approximated by a hyperbolic function). In addition, Gollier (2002) has shown that when future consumption growth is uncertain, the appropriate discount rate falls over time. Finally, Weitzman (1998) shows that any uncertainty in the discount rate leads to a declining discount rate over time. Further arguments in favour of DDR can be found in Groom et al. (2005).

As an illustration, consider the case of applying different discount rates to flood-defences investment. In this case, declining discount rates may also have an effect on the economics of flood protection. Since the mid 1990s, flood-defence investment has been characterized by annual expenditure that has been assumed to offset significant damage – a cost-benefit ratio much greater than unity.

The figure shows the different cost-benefit ratios for various discount schemes. Employing a 6 per cent discount rate implies that flood-defence investment does not pass the cost-benefit analysis. However, a benefit-cost ratio of approximately 1.2 is obtained with a 3.5 per cent discount rate.



Benefit-cost ratio for flood defences

Source: Shrewsbury FAS project estimates and OXERA calculations. OXERA (Groom, B., Hepburn, C., Koundouri, P., David, P. and Smale, R.) (2002) *A Social Time Preference Rate for Use in Long-term Discounting*, Report to the Office of the Deputy Prime Minister and the Department for Environment, Food, and Rural Affairs

Furthermore, flood defences are more attractive under all declining rate regimes than under either a 6 per cent or 3.5 per cent fixed-rate regime. The benefit-cost ratio increases by about 17 per cent when the step schedule of discount rates is employed instead of a flat 3.5 per cecnt rate.

For short-term projects with time horizons of less than 30 years, declining discount rates have only minimal impact, as noted in Table 2. However, for projects with time horizons over 30 years, employing declining discount rates may have a significant impact on the preferred policy. In many such cases (such as road construction), shifting from a 3.5 per cent flat rate to the step schedule of rates could result in an increase in net present value from 8 per cent to 40 per cent.

When time horizons exceed 100 years, the potential impact is even greater. As Table 2 illustrates, it is estimated that the effect could be an increase or decrease of up to approximately ±100 per cent of net present value. For projects with costs and benefits accruing over a time horizon of 200–400 years (such as climate change mitigation), the step schedule of declining discount rates might have an impact of up to approximately ±150 per cent on net present value, relative to discounting at a 3.5 per cent constant rate.

Table 2 Effect of shift from flat 3.5 per cent to the step schedule of discount rates

Project time horizon	Potential effect on project net present value
0–30 years	Small, generally insignificant
30–100 years	Significant (± 50%)
100–200 years	Large impact (± 100%)
200–400 years	Major impact (± 150%)

Source: Shrewsbury FAS project estimates and OXERA calculations. OXERA (Groom, B., Hepburn, C., Koundouri, P., David, P. and Smale, R.) (2002) *A Social Time Preference Rate for Use in Long-term Discounting*, Report to the Office of the Deputy Prime Minister and the Department for Environment, Food, and Rural Affairs

Conclusion

The importance of appropriate economic considerations in all aspects of water resources management is being recognized increasingly. This chapter has presented the necessary procedures for implementing an integrated approach from an economic perspective, and the identification of economic instruments and measures that are able to evaluate the true economic cost of water and to provide policymakers with the tools to allocate water in an efficient manner. The theory and applications of these valuation methods and the economic instruments have been described. Finally, a methodology for implementing a methodology that takes into consideration the efficiency aspects of water allocation, as well as the equity, environmental and sustainability issues, was presented. Together, these can help to provide policy prescriptions that endeavour to offer an integrated water resources management framework.

GUIDE TO FURTHER READING

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