TOWARDS A COMMON METHODOLOGY FOR MEASURING IRRIGATION SUBSIDIES

DISCUSSION PAPER

June 2008

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The Global Subsidies Initiative
of the International Institute for Sustainable Development

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Towards a common methodology for measuring irrigation subsidies

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Abbreviations and acronyms

AJE	Alternative Justifiable Expenditures
AoA	Agreement on Agriculture
COAG	Council of Australian Governments
DRC	Domestic Resource Cost
EAI	Environmental Assessment Institute
EU	The European Union
FR	Flat Rate
GHG	Greenhouse Gas
GSI	Global Subsidies Initiative
GWI	Global Warming Intensity
ICID	International Commission for Irrigation and Drainage
IISD	International Institute for Sustainable Development
MCM	Million Cubic Meters
MPP	Marginal Physical Product
MVP	Marginal Value Product
NWI	National Water Initiative
OECD	Organisation for Economic Co-operation and Development
O&M	Operation and Maintenance
PWI	Public Works Index
Rs	Rupees
SAM	Social Accounting Matrix
SCRB	Separate Costs, Remaining Benefits
TVA	Tennessee Valley Authority
UNEP	United Nations Environment Programme
WFD	Water Framework Directive
WTP	Willingness to Pay
WUA	Water User Association
WWI	World Watch Institute
UNCTAD	United Nations Conference on Trade and Development
UOF	Use-of-Facilities
USDA	U.S. Department of Agriculture
WTO	World Trade Organization
$	U.S. dollars at their 2006 value

Executive summary

Irrigation accounts for 70 to 90 percent of total water use in developing countries and for more than one third of water use in many Organisation for Economic Co-operation and Development (OECD) countries. The significance of irrigation in increasing agricultural production and in meeting the food-grain requirements of the world has been well recognized. In addition to helping increase agricultural productivity and agricultural production, irrigation has also been credited with helping increase the incomes of farmers, in tackling problems of rural poverty and in keeping prices of food lower than they would otherwise be.

The world over, most irrigation systems have been built and operated by government agencies. Typically, irrigation water users are charged only a fraction of the cost of supplying water to them. In many cases, these charges fail to even cover operation and maintenance (O&M) costs, and they almost never cover any of the substantial capital costs incurred in developing water collection and distribution systems. Whatever the logic, the form of defining subsidies or the amount of subsidies given, these subsidies in general have discouraged more efficient use of available water.

Available estimates of irrigation subsidies are generally derived as the difference between the cost of supplying irrigation water and the revenue realized from beneficiaries from the sale of irrigation water. Irrigation water provisioning is a complex undertaking. Most large-scale irrigation projects are multi-purpose in nature. These projects have been built over several decades and are still in service. While most large projects have been built and are being operated and maintained by governments or their agencies, small groundwater-based systems are typically owned, operated and maintained by individual farmers. The provision and use of irrigation water are associated with a number of externalities—both economic and environmental—whose costs have to be borne by governments or society. Irrigation water use is also associated with significant opportunity costs, as other potential users are being deprived of the water being used for irrigation.

Given all these intricacies associated with irrigation water, estimating the cost of irrigation water is not easy. Several issues need to be resolved. How should the capital costs of irrigation be apportioned in multi-purpose projects? Should the capital cost of existing infrastructures be treated as a sunk cost? If not, how much of the capital cost invested in irrigation projects during last several decades should be accounted for? How should the opportunity cost of irrigation water be measured? Should the cost of externalities be counted when estimating the cost of irrigation? Are the necessary data available to estimate these costs? Does a clear conceptual framework exist to estimate various costs?

As on the cost side, there are similar questions on the revenue-realization side. Are farmers the only beneficiaries of irrigation water? Should farmers pay for all the costs of irrigation? Are there any other revenues for the government from irrigation water? Are enough data available to estimate revenues?

Answering the above questions is not easy. Given the complexities surrounding the estimation of the costs of irrigation water and the subsequent revenue realization, one often wonders if these complexities have been satisfactorily taken into account in previous estimates of irrigation subsidies. A perusal of the available estimates of irrigation subsidies suggests that an assortment of methods have been used. While some estimates equate the cost of irrigation only with the current O&M cost of irrigation works, others equate irrigation cost with O&M cost plus some fraction of capital cost without clarifying how the cost of multi-purpose projects have been apportioned and how the capital invested in the past has been accounted for. There is invariably no accounting of opportunity cost or the cost of externalities in any of the available estimates.

There is as yet no internationally agreed method for estimating irrigation subsidies and since available estimates differ both on conceptual and methodological levels, and often lack transparency in their use of the data, the estimates so derived do not render themselves comparable. Nevertheless, it is not too soon to establish the necessary groundwork for measuring subsidies for irrigation so that better, and internationally comparable, estimates become available sooner rather than later. With the advent of the World Trade Organization (WTO), issues relating to subsidies have come to more prominence and efforts to define, measure and analyze subsidies in various sectors have gained momentum.

This discussion paper attempts to help define a methodology for estimating irrigation subsidies that can be applied to estimate and report irrigation subsidies in a manner that is comparable across a range of developing and developed countries. A related objective is for the results of this research to lead to the improvement of other research efforts (notably policy modelling) and, ultimately, to improvements in both domestic policies and international trade rules.

The paper provides a methodological framework to estimate subsidies from two different perspectives: (a) from the perspective of the irrigation-water-supplying agency (the cost to government); and (b) from the recipients' point of view (benefit to the recipient).

Estimates of irrigation subsidies depend upon identification and measurement of three key constituents: cost; beneficiaries; and revenues. Depending upon the perspective of the analyst the meaning and methods of measurements of the three key constituents can differ.

Following the cost-to-government approach, the subsidy is estimated as the difference between the gross cost to the government and the revenue realized from making available irrigation water. The annual cost of making irrigation water available has been defined as the sum of the following costs:

- Annual capital cost (interest and depreciation charges) of irrigation infrastructure;
- O&M costs;
- Cost of providing water through groundwater;
- Opportunity cost of irrigation water;
- Opportunity cost of electricity used for irrigation pumping;
- Resource cost of groundwater; and
- Cost of environmental externalities (insofar as they can be quantified and attributed to government expenditure).

The total revenue to the government from investments made in the provision of irrigation water comprise:

- Revenue realized on sales of water;
- Revenue realized from the sale of hydropower;
- Revenue realized from the sale of fishing rights;
- Revenue realized on account of the sale of electricity to the agricultural sector for irrigation pumping;
- Revenue realized on account of increased tourism and tourist-related activities; and
- Revenue from the imposition of pollution taxes, insofar as they relate to the provision and use of irrigation water.

The estimation of each of these components of costs and revenues is in itself a complex process. The paper describes in detail the methods that can be employed to deal with these complexities and the approach that can be used to quantify various costs and revenues.

The second approach to measurement of subsidies is based on the value of water to the irrigator rather than the amount of expenditure incurred by the government. Thus the irrigation subsidy following this approach is the difference between the water's net economic benefit to the irrigator per unit of water and the price paid per unit of water.

The estimation of benefits and costs to the beneficiary are equally difficult, though somewhat less cumbersome. Following this approach, the total benefits of irrigation water to users, to the extent these benefits can be quantified thus:

- Benefits to direct beneficiaries;
- Increased incomes of those indirectly benefited; and
- Benefits of return flows.

The total cost to the users of groundwater is the sum of the following:

- User charges for surface and groundwater; and
- Costs of mitigation of degraded soils and environmental externalities.

An important constraint in the estimation of irrigation subsidies following either approach is the non-availability of—or denial of access to—detailed and disaggregated data on a large number of variables. Therefore the first-time data requirements for estimating irrigation subsidies following the approaches suggested here are enormous and may require substantial financial and human resources, and time, to collate data from different sources and put them into a useable format. However, once the historical data sets have been obtained and put in the framework, their subsequent updating should be relatively straightforward.

To empirically validate the methodologies suggested in this paper and to test their robustness in generating more comparable inter-country estimates of irrigation subsidies, it would be appropriate if at least two empirical case studies—one in a developing country and the other in a relatively developed country—were undertaken.

1 Introduction

1.1 Overview

Irrigation is the major consumptive user of water in a large number of countries. Irrigation is also one of the leading inputs influencing the pattern of agricultural production and the level of agricultural productivity. Crop yields on irrigated lands are generally higher and less variable than those on un-irrigated lands. Much of the increase in global agricultural production over the last several decades can be attributed to the expansion of irrigation. Since the availability of irrigation influences the feasibility of cultivating a particular crop, such as cotton, in a given region, the policies of governments, financiers and owners of most of the large irrigation projects worldwide can have far reaching influence in shaping the pattern of agricultural development and trade.

The operation of the World Trade Organization's (WTO) Agreement on Agriculture (AoA), however, overlooks this reality to a large extent. It classifies government expenditure on irrigation in the Green Box (Annex 2 of the AoA)—i.e., among other domestic programs exempted from AoA reduction commitments. As per Article 2(g) of Annex 2:

> *Such programmes, which include but are not restricted to the following list, shall meet the general criteria in paragraph 1 above and policy-specific conditions where set out below: … (g) infrastructural services, including: electricity reticulation, roads and other means of transport, market and port facilities, water supply facilities, dams and drainage schemes, and infrastructural works associated with environmental programmes. In all cases the expenditure shall be directed to* the provision or construction of capital works only*, and* shall exclude the subsidized provision of on-farm facilities *other than for the reticulation of generally available public utilities.* It shall not include subsidies to inputs or operating costs, or preferential user charges.

In essence, the Green Box allows governments to provide general infrastructure (for example, canals for irrigation), but treats the "subsidized provision of on-farm facilities" or "subsidies to inputs or operating costs, or preferential user charges" as part of Amber Box support. The Green Box is, by definition, reserved for domestic support measures that have "no, or at most minimal, trade-distorting effects or effects on production." Yet significant technical difficulties are involved when assessing whether irrigation programs result in subsidies to inputs for agricultural production, or generate more than "minimal, trade-distorting effects or effects on production." As a result, agricultural experts have historically shied away from concerted—much less universal—attempts to undertake such assessments; this fact is clear in the highly inconsistent reporting of irrigation subsidies in AoA notifications (WTO's Agreement on Agriculture (AoA)).

Although incomplete, the cover provided for irrigation projects under the AoA remains untested to date. To an extent, this ambiguity has alleviated pressure on WTO Members to estimate the agricultural support they provide through irrigation. The imprecision of Green Box measures themselves has also emerged as an issue of concern within the current WTO negotiations on agriculture.

Estimating subsidies to irrigation and allocating them to specific crops, however, is not a simple task. A major difficulty for analysts is the site-specific nature of the subsidies. The structure of the charges, the degree of cost-recovery built into water charges, and of cross-subsidization among different users of multiple-use infrastructure, can vary from water project to water project. There is also as yet no internationally agreed method for estimating the subsidy equivalent of prices for water that are below those charged to other consumers, after adjusting for differences in quality and interruptibility. Nevertheless, it is not too soon to establish the necessary groundwork for measuring subsidies to irrigation so that better, and internationally comparable, estimates become available sooner rather than later.

Driven by these concerns, the Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD) has initiated a major research effort in the area of irrigation subsidies. As part of this initiative, this paper attempts to promote the adoption of a methodology for estimating irrigation subsidies that can be applied to estimate and report irrigation subsidies in a manner that is comparable across a range of countries. A related objective is for the results of this research to lead to the improvement of other research efforts (notably policy modelling) and, ultimately, to improvements in both domestic policies and international trade rules.

1.2 Outline of the study

In the following paragraphs, we discuss the concept of subsidies in general. This is followed by a brief discussion on the concept of a subsidy in the irrigation sector and the methodological problems associated with developing a uniform measure of irrigation subsidies. Section 2 gives an overview of irrigation subsidies in some of the countries and regions of the world. The magnitude of subsidies within and across different countries is likely to differ not only by the methodology employed to quantify subsidies but also the perspective of the agency trying to estimate those subsidies. In Section 3 we discuss alternative approaches to quantifying irrigation subsidies. Sections 4 and 5 describe the complexities of quantifying various costs and benefits of making irrigation water available, and attempts to estimate irrigation subsidies from the perspective of the water-supplying agency vis-à-vis the government. Section 6 looks at the quantification of subsidies from the perspective of the recipients.

The methodological problems associated with estimating subsidies by either approach are often compounded by the scarcity of data required to measure the costs and benefits of irrigation. While part of the problem relating to data scarcity can be ascribed to poor data collection efforts by the water-supplying authority, part of the problem arises due to an unwillingness of government authorities to provide access to the data. Section 7, therefore, discusses some of the issues relating to the availability and sources of data. The last section summarizes the main points of the study.

1.3 What are subsidies?

Although subsidies in general account for a significant proportion of annual government spending in almost every country, multiple definitions of subsidies are in use primarily because the nature, form, context and purpose of giving subsidies—and economic and policy goals aimed to be achieved by giving subsidies—have differed across countries. The definitions differ even within a country between different sectors and during different periods of time. For example, subsidies can take the form of budgetary payments or support involving tax expenditures (various tax provisions that reduce the tax burden of particular groups, producers or products), market price support, subsidized input prices, preferential interest rates, foregone tax revenues or foregone resource rents. Similarly, different approaches to measuring subsidies are used for specific purposes, fields (e.g., agriculture or transport) or contexts (e.g., domestic concerns or international trade).

Coupled with these concerns, the definition of a subsidy and approaches to its estimation have also often been customized to suit the nature of available data, the amenability of different parameters to quantification and even the convenience of the institution or analyst attempting to estimate the subsidy. A small change, therefore, in the characterization of subsidies or a small modification in the method of estimation of subsidies can cause the calculated value to vary considerably. As a result, the concept, and therefore estimates of subsidies in a given sector across countries or across different sectors within a country have frequently been inconsistent and not comparable.

In general, subsidies have frequently been implied to "comprise all measures that keep prices for consumers below market level or keep prices for producers above market level or that reduce costs for consumers and producers by giving direct or indirect support" (see, for example, de Moor and Calamai, 1997, and de Moor, 2001). A more inclusive definition of subsidies has been offered by the Environmental Assessment Institute (2005):

> subsidies comprise all measures that keep consumer price at a level below that which reflects the true opportunity cost that would prevail in competitive markets if all external costs and benefits were internalized (externalities are internalized when they are assigned a price and thus enter in to the market on equal terms with other traded goods and services) or all measures that keep producers prices above true opportunity costs in competitive markets if all external costs and benefits were internalized or that reduce costs for consumers and producers by giving direct and indirect support.

The WTO Agreement on Subsidies and Countervailing Measures provides a definition of the term "subsidy" that contains three basic elements: a financial contribution; made by a government or any public body within the territory of a Member; and which confers a benefit. All three of these elements must be satisfied in order for a subsidy to exist.

1.4 Subsidies for irrigation water: the issues and the rationale for the present study

As in the case of general subsidies, the concept of subsidies in the water sector is no less complicated—there are many forms of subsidies and many ways of defining and measuring them. The nature, form and objectives of providing water subsidies also differ across water-using sectors within a country and for a given water-using sector across countries. In the case of developing countries, for example, the objective of giving irrigation subsidies could be a combination of some or all of the underlying factors, such as rural development, encouraging technological adoption by resource-poor farmers, achieving greater food production, poverty alleviation, employment generation, social equity concerns, etc.; in the case of developed countries, by contrast, the objective of giving irrigation subsidies is often simply to increase farm incomes, and to make their products more competitive on the international market and thereby increase agricultural exports.

Irrigation accounts for 70 to 90 percent of total water use in developing countries and for more than one third of water use in many OECD countries. Irrigated agriculture occupies about 17 percent of the planet's cultivated land but provides about 40 percent of the world's food supply. The production of food and fibres under irrigation makes up 72 percent of world water abstractions (FAO, 1999). In Africa and Asia, irrigation water makes up more than 80 percent of the continents' abstractions. In countries like Mexico, Spain, Turkey and the United States, more than 70 percent of the irrigated acreage relies on surface waters that originate from highly controlled river basins (OECD, 1999). The significance of irrigation and irrigated agriculture in increasing agricultural production and in meeting the food-grain requirements of the world has been well recognized. In addition to helping increase agricultural productivity and agricultural production, irrigation has also been credited with helping increase the incomes of farmers, in tackling problems of rural poverty and in keeping prices of food lower than they would otherwise be.

Given that irrigation is the predominant use of water in most countries, the pattern of water use in irrigation has also influenced the overall patterns of water use, inter-sectoral allocation of water and, above all, the efficiency of water use. Irrigation development and use have also been associated with a number of environmental externalities in the form of groundwater depletion, increased run-off, pollution of surface water bodies and groundwater aquifers, soil salinity and waterlogging, among others.

The world over, most irrigation systems have been built and operated by government agencies. Typically, irrigation water users are charged only a fraction of the cost of supplying water to them. In many cases, these charges fail to even cover operation and maintenance (O&M) costs, and they almost never cover any of the substantial capital costs incurred in developing water collection and distribution systems (Repetto, 1986; Tsur and Dinar, 1995). Charges are generally based on the area irrigated rather than on the amount of water used. The economic and environmental externalities associated with the supply and use of irrigation water is almost never internalized. Whatever the logic, the form of defining subsidies or the amount of subsidies given, subsidies in general have discouraged more efficient use of available water.

Subsidies on irrigation water in both developing and developed countries alike have been pervasive. Several estimates are available on the amount of subsidies going to the irrigation sector. Based on a World Bank study in 1994, Van Beers and de Moor (2001) estimate irrigation subsidies in developing countries at \$20 billion to \$25 billion per year, with a majority of these given in Asia. Myers and Kent (2001) estimate irrigation subsidies in developing countries at around \$29 billion. Both Myers and Kent (2001) and Van Beers and de Moor (2001) estimate total water subsidies in OECD countries at \$15 billion per year, the majority of which are for the irrigation sector. Brown *et al.* (2000) gave an estimate of \$33 billion per year for global irrigation subsidies. These estimated subsidies are those given directly to the irrigation sector, without taking into account the cost of externalities.

The above estimates are likely conservative and vary substantially depending upon how the subsidies are defined. In the mid-1980s, irrigation subsidies in six Asian countries covered an average of 90 percent or more of total O&M costs (Repetto, 1986). During the 1990s, subsides declined somewhat, as most countries had officially adopted the stated goal of moving towards full recovery of O&M costs. No country in either the developed or the developing world has fully eliminated subsidies, however, and progress on this front has been uneven, with Chile and South Africa in the vanguard. Despite these ongoing reforms, O&M cost recovery remains dismal in most major irrigating countries. In developing countries, the recovery of irrigation O&M ranges from 20 to 30 percent in India and Pakistan up to 75 percent in Madagascar, and depreciation is virtually uncovered (Dinar and Subramanian, 1997). According to another study (Sur *et al.,* 2002), farmers across the world seldom pay more than 20 percent of the full cost[1] of water. The study also claims that "full [cost] recovery, to the best of our knowledge, including the recovery of the full investment cost, has not been practiced anywhere" (Sur *et al.*, 2002).

Without going into the reasons for low cost-recovery rates in different countries and without going into the desirability or otherwise of providing large irrigation subsidies in these countries, limited cost recovery in irrigation has meant that extensive contributions from governments' public investment and current expenditure budgets have been necessary to maintain irrigation systems. The failure of charges to cover even O&M expenses has often resulted in the long-term deterioration of irrigation systems. In Mexico, for example, the area irrigated declined during the late 1980s after the government cut back spending, because it was dependent on subsidies (89 percent subsidy rate). Insufficient funding for maintenance in China has kept more than 930,000 hectares of irrigated farmland out of production since 1980. Worldwide, an estimated 150 million hectares—more than 60 percent of the world's total irrigated area—need some form of upgrading to remain optimally productive (Gleick, 1993).

Available estimates of irrigation subsidies are generally derived as the difference between cost of supplying irrigation water and the revenue realized from the sale of irrigation water. Yet irrigation water provision is a complex undertaking. Most large-scale irrigation projects are multi-purpose in nature. These projects will often have been built over several decades and are still in service. While most of the large projects have been built and are being operated and maintained by governments or their agencies, small groundwater-based systems are typically owned, operated and maintained by individual farmers. The provision and use of irrigation water are associated with a number of externalities—both economic and environmental—whose costs have to be borne by governments or society. Irrigation water use is also associated with significant opportunity costs.

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[1] Full cost here refers to the financial cost.

Given all the intricacies associated with irrigation water, estimating the cost of irrigation water is not easy. Several issues need to be resolved. How should the capital costs of irrigation be apportioned in multi-purpose projects? Should the capital cost of existing infrastructure be treated as a sunk cost? If not, how much of the capital cost invested in irrigation projects during the last several decades should be accounted for? How should the opportunity cost of irrigation water be measured? Should the cost of externalities be counted when estimating the cost of irrigation? Are the necessary data available to estimate these costs? Does a clear conceptual framework exist to estimate various costs?

As on the cost side, there are similar questions on the revenue-realization side. Are farmers the only beneficiaries of irrigation water? Should farmers pay for all the costs of irrigation? Are there any other revenues for the government from the impoundment and sale of irrigation? Are enough data available to estimate revenues?

Answering the above questions is not easy. Given the complexities surrounding the estimation of the costs of irrigation water and the revenue realized thereafter, one wonders if these complexities in the estimation of costs and revenues have been addressed in the available estimates of irrigation subsidies. A perusal of methods employed in arriving at some of the available estimates of irrigation subsidies suggests that an assortment of methods have been used. While some estimates equate cost of irrigation with only the current O&M cost of irrigation works, others equate irrigation cost with O&M cost plus some fraction of capital cost without clarifying how the costs of multi-purpose projects have been apportioned and how the capital invested in the past has been accounted for. There is invariably no accounting of opportunity cost or the cost of externalities in any of the available estimates. Since the available estimates differ both on conceptual and methodological considerations, and documentation of the data is usually poor, the estimates so derived are not comparable. A consensus on a working and widely acceptable definition of subsidies, and their methods of measurement, is important, however, if subsidies are to be measured in a way that makes their estimates more meaningful, comparable and useful across nations.

With the advent of the WTO, issues relating to subsidies have come to more prominence and efforts to define, measure and analyze subsidies in various sectors have made some progress. Factors contributing to the relatively modest progress in measuring subsidies range from complex methodological and data issues to a lack of political will to provide reliable and internationally comparable subsidy figures. Trade-offs are made both at national and international levels as data collection is often resource intensive and aggregate subsidy estimates are only as good as the underlying data (Steenblik, 2003).

2 Brief review of irrigation water policies and subsidies in selected countries

Probably nowhere in the world are large-scale irrigation works treated as commercial undertakings. For either economic or political reasons, the full cost of providing irrigation is never recovered. Since only a part of the cost is recovered, an amount of subsidy is therefore always built into the provision of irrigation water. As discussed in the previous section, subsidies for irrigation water in almost all countries are measured as the difference between public expenditure on irrigation less revenue received in the form of water charges from irrigators. Public expenditure on irrigation can, however, be interpreted to imply either some measure of capital cost and operations and maintenance (O&M) cost, or more generally O&M costs alone.

In practice, most countries seek only to recover annual O&M costs and possibly some fraction of capital-investment costs. Again, in most countries even the O&M costs are rarely recovered in full, typically varying between 20 and 80 percent of the cost. Water tariffs are generally fixed on political or social considerations, and have little or no economic basis for their fixation. Often these charges are not recovered on the basis of the actual quantity of water utilized but on some measure of non-volumetric consumption. Macro-economic concerns of resource allocation between sectors, pollution charging and benefit taxation, though recorded in the theoretical reasoning, have seldom been the key drivers of national policies relating to water. The resource cost for depleting groundwater is not recovered. Frequently, farmers are supplied electricity for groundwater pumping, either free or at a price which is much lower than the social cost of generating and distributing the electricity.

Given the mounting load of irrigation subsidies in many countries, almost all countries have undertaken to recover at least the O&M cost of the irrigation systems from the users. Given that the raising of irrigation prices can be a politically sensitive issue, limited success has been achieved in improving O&M cost recovery. Some parts of the world, such as the European Union (EU), are now moving towards full cost recovery. China has also shown its intent in moving towards a system of full cost recovery.

In the following paragraphs there is very brief description of the status of irrigation subsidies in some regions and countries of the world.

2.1 OECD countries

In Organisation for Economic Co-operation and Development (OECD) countries there are two main forms of subsidies provided to water projects: grants and low-interest loans. The weight of water subsidies is uneven and particularly high in Australia, Greece, Japan, Mexico, Spain, Turkey, and the United States. Most subsidies are earmarked for capital expenditures, with grants covering on average between 20 to 40 percent of total costs, but reaching up to 80 percent for irrigation projects. Most of the costs of investment in irrigation still fall on the taxpayer and on other water users (through cross-subsidies). And it is, in the main, national treasuries that have financed dams, reservoirs and delivery networks, as well as a large part of the cost of installing local and farm infrastructure. Many irrigation projects are not intrinsically economically viable *per se*, and are carried out only because of the enormous subsidies involved. Several studies have shown that irrigation water tends to be extremely underpriced in OECD countries (Dinar and Subramanian, 1997). Governments generally attempt to recover some of these costs through user charges on irrigation water supply. However, due to extreme under-pricing of irrigation water, revenues realized from these charges are rarely enough to cover even O&M costs. In regard to resource charges, as a rule, farmers have free access to (or are charged only a nominal fee for) water that they pump themselves. And several OECD countries continue to offer preferential tariffs for electricity used to pump water for irrigation.

There are, however, wide differences among different OECD countries. These countries are at very different stages in developing water-pricing systems in agriculture. The wealthier countries of the OECD stand out where there is reported to be full recovery of annual O&M costs and some recovery of capital costs. These include Japan, France, Australia, Spain and the Netherlands. However, in the overwhelming number of cases, water charging does not cover even annual O&M costs (UNCTAD, 2005).

The economic distortions caused by the under-pricing of water used in agriculture have been compounded in many instances by agricultural policies, particularly those linked to the production of particular commodities. Such linked support draws resources, including water, into the activity being supported, thereby driving up both the price of water to other users and the volume of agricultural subsidies.

2.2 Non-OECD Mediterranean countries

Mediterranean countries have invested heavily in irrigation schemes to secure and increase agriculture water supply in order to develop this economic sector, to improve food security and to target populations in less-favoured rural areas. The state has made water available at a low cost to farmers through public financing. This policy has resulted in highly subsidized irrigated agriculture (Abu-Zeid, 2001) where low water prices have contributed to the extension of irrigated areas, increases in agricultural water demand and the misallocation of the resource among users and uses. Low-cost recovery and poor maintenance have caused infrastructure deterioration and poor water distribution efficiency and irrigation performance.

These past policies have since reached their limits to ensure adequate financial balance and to control water demand. Governments have been compelled to revisit their policies and engage in pricing reforms in order to improve cost recovery and, more recently, to shift to demand-management policies. Pricing experiences in Mediterranean countries are now, in general, being oriented towards the objective of cost recovery whereby the resources for O&M, minimally, must come from the direct beneficiaries—the water users. Such policies have contributed to the reduction of public financing at least with respect to O&M costs of irrigation schemes such as in Tunisia and Morocco. More rarely, a portion of capital costs is charged to farmers. One such example is that of France, where users are supporting a portion of capital costs—varying from 20 to 50 percent on average. These steps, it is expected, will lead to a more durable water infrastructure.

There are again wide disparities within the region in regard to charging for irrigation water. At the one extreme are the cases where water is free (Egypt and Albania), which does not encourage water saving at all. At the opposite extreme, Israel has introduced a pricing structure with increasing block-rate pricing that gives a strong incentive to save water. Between these two situations, a wide range of pricing policies exists (in increasing order of effectiveness): area pricing; area pricing depending on the crop being irrigated or other criteria; uniform or two-part volumetric pricing; and increasing block-rate pricing.

2.3 China

The agricultural sector is the main water-using sector in China, accounting for almost 70 percent of the country's total water use. Under its system of collective agriculture, the costs of water resource development and water supply were usually not calculated at all. Farmers had to contribute labour to the construction and maintenance of water projects, but water was generally free of charge. After the reforms of the late 1970s, methods for charging for irrigation water were introduced. Although the charges have since risen in nominal terms, real prices for water have increased little or have even remained constant over time (Lohmar *et al.*, 2003; Wang and Huang, 2001; Yang *et al.*, 2003). Today, irrigation water charges cover only 36 percent of supply costs on average, and the Chinese government still heavily subsidizes agricultural water use (Yaozhou and Bingcai, 2002; Lohmar *et al.*, 2003).

Of late, these subsidies are increasingly being considered to be a burden by the government. The Chinese government had hoped that higher water prices would induce water savings, help improve the allocation of water supplies among sectors and raise sufficient funds for infrastructure maintenance and rehabilitation. However, this did not happen. In order to be an effective tool for demand management and to recover the cost of water supply, water charges would have to rise significantly. This is a difficult social and political task and not easy to implement. Upper limits set by the government have kept system officials from increasing water prices and achieving, at least, the recovery of O&M costs (Li and Li, 2002; Nyberg and Rozelle, 1999). In many places, water charges now aim at recovering at least the primary costs of system operation (Lin, 2002). In the case of groundwater that is extracted from privately owned wells, farmers pay only the costs of power and equipment, but nothing for the water itself. Some provinces, however, are considering the introduction of a groundwater resource levy in order to restrict groundwater use to sustainable levels (Jin and Young, 2001; Yang *et al.*, 2003).

The Central Government of China proposed a regulation on water pricing called "Price regulation of water supply projects," which started to be implemented in 2004. The new Chinese water policy aims at the full cost recovery of the cost of water supply. It stresses the fact that water should be treated as an economic good and should be priced accordingly. But although China has included a so-called resource charge in its laws and regulations, this charge is more linked to administration costs rather than to opportunity costs and externalities (World Bank, 2001; and 2002). This notion of full cost recovery refers to O&M costs and the overhaul and replacement costs of water supply infrastructure (World Bank, 2001).

2.4 India

In India, the agricultural sector is the main user of water: irrigation accounts for about 80 percent of total water use. The need for making irrigation water available to farmers on a priority basis came with the introduction of high-yielding crop varieties in the mid-1960s. Driven by acute food-grain shortages and the objective of attaining self-sufficiency in food-grains, the government took upon itself the burden of providing irrigation water (and some other inputs) at prices that were considered affordable and that could encourage farmers to adopt new technologies and help increase food-grain production. In the case of irrigation water, this was reflected in the form of subsidies for surface water and for groundwater, and it was reflected also in the supply of electricity either free or at a price much below the cost of generating and distributing the electricity. These policies succeeded in achieving their desired objectives and India soon achieved self-sufficiency in food-grains.

Given the politically sensitive nature of irrigation water prices in rural India, successive governments did not do much to raise the prices of irrigation water, and for several years (and in some cases for several decades) there was no increase in the water charges. The government has always taken the public posture of intending to recover at least O&M costs. In reality, however the proportion of O&M costs recovered from the farmers has declined over time. Gulati and Narayanan (2003) estimate that the irrigation subsidies on major, medium and minor irrigation projects have grown from about Rs 2,700 million ($67,264,574) in 1980–81 to more than Rs 43,000 million ($1,071,250,623) in 1999–2000, though these estimates could vary somewhat depending upon how one defines a subsidy. The low irrigation rates and mounting subsidies on account of irrigation water has led to the inefficient use of irrigation water, exacerbated water shortages and raised concerns about meeting future food-grain requirements, failure to prevent deterioration of infrastructure and constraints on the availability of funds for new investment. Concerned by the mounting subsidies, the government appointed a high-level committee on pricing of irrigation water in 1992 to help draw a roadmap for revision of irrigation water rates (Vaidyanathan, 1992). The committee recommended full recovery of O&M costs and a recovery of one percent of the cumulative capital expenditures incurred in the past at historical prices from the farmers. However, almost 15 years after the commission submitted its report, the government has yet to implement its recommendations. As a result, the burden of subsidies has continued to rise.

2.5 Australia

The Australian government has recently introduced major reforms in the water sector. The states and territories have committed to the National Water Initiative (NWI) reforms in the area of best-practice water-pricing and institutional arrangements. A central tenet of these reforms is to achieve consistency in water-pricing policies across states and territories and sectors for water storage and delivery, and to achieve consistency in approaches to pricing, and attributing costs of, water-planning and management. Under the NWI, the aim was to achieve consistency in pricing policies across sectors and jurisdictions in Australia where "entitlements are to be traded"[2] by 2006. Similar consideration is also being given to the development of consistent approaches to charging where the operation of water markets is limited.

Under the NWI, governments have agreed to full cost recovery for all rural surface- and groundwater-based systems through achievement of lower-bound pricing, and continued movement towards upper-bound pricing for all rural systems where practicable. The Council of Australian Governments' (COAG) definition of lower-bound pricing is the setting of water charges sufficient to recover the operational, maintenance and administrative costs, externalities, taxes or tax equivalents (not including income tax), the interest cost on debt, dividends (if any) and provision for future asset refurbishment or replacement. If a dividend is paid, it should be set at a level that reflects commercial realities and stimulates a competitive market outcome. Upper-bound pricing is setting water charges that are above lower-bound charges, but avoid monopoly rents. The concepts of upper- and lower-bound pricing have been designed to provide a band within which prices should lie. Lower-bound pricing provides for the recovery of costs only, while upper-bound provides for the recovery of costs, including a rate of return on capital, but avoiding the earning of monopoly rents.

The level of subsidies given under the Australian system is determined in the process of working out the revenue requirements and the proportion of revenue that is to be recovered. The charges are set by Economic Regulators in each jurisdiction and the process of fixing charges is based on an assessment of the "revenue required" by the water agency, to cover the costs of providing the services in an efficient manner and on a sustainable basis. In broad terms, the revenue requirement reflects both the operating costs (operating, maintenance, administration, bad debts and working capital) and the capital costs (replacing assets, expansion, depreciation and funding). Having determined the revenue requirement, the water authority or government then determines the proportion of the revenue requirement to be recovered through user charges. Some of that revenue may also be recovered through government contributions, including Community Service Obligations.

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[2] Intergovernmental agreement on a National Water Initiative (NWI) taken from the Web site of the Australian Government's National Water Commission, accessed on 14 April 2008, from http://www.nwc.gov.au/nwi/index.cfm

3 Approaches to quantifying irrigation subsidies

As already discussed, defining and estimating irrigation subsidies is quite challenging. The extent to which irrigation is subsidized will depend upon the perspective of the person or agency attempting to estimate these subsidies and the concept with which one chooses to define costs of providing irrigation water, the returns from irrigation water and the subsidies. Broadly speaking, irrigation subsidies can be defined from three different perspectives (Gulati and Narayanan, 2003).

(a) *From the perspective of the irrigation water-supplying agency.* From the perspective of the government or supplier, an irrigation subsidy is defined as the net cost to the government in making irrigation water available. From this angle, one can conceptualize an irrigation subsidy as the difference between the cost of making irrigation water available and the revenue received as payments from the beneficiaries of irrigation water. Thus, this concept is akin to that of "losses" incurred by the irrigation authority or supplier in delivering irrigation water. There are, however, three major issues that need to be resolved before one can arrive at the true measure of "loss" or subsidy from the perspective of the supplier. The first concerns defining precisely the concept "cost" of irrigation water and identifying the relevant components which make up this "cost." The second concerns identifying the users or beneficiaries of the water. The third concerns defining the "revenue" realized from the beneficiaries of this water.

(b) *From the recipients' point of view – benefit to the recipient.* From the beneficiary's point of view, irrigation subsidies should relate to the actual value of water to the beneficiaries rather than the amount of public expenditure incurred in making water available. From the beneficiary's point of view, therefore, an irrigation subsidy would measure the difference between one's willingness to pay (WTP) for the water and what one actually pays. One's WTP for water could be equated to what one gets from water in terms of additional production—that is, the marginal value product (MVP) of water at different levels. Thus the difference between the MVP of water and the actual payment of water is the net benefit from the beneficiary's perspective. In terms of micro-economic theory this is akin to the concept of consumer surplus. Repetto (1986) and Roumasset (1987) term this surplus as "economic rent."

(c) *From the perspective of the society at large.* This would amount to defining an irrigation subsidy as the difference between the true domestic resource cost (DRC) of providing irrigation water to farmers and what farmers pay to the society for irrigation in terms of their direct price for water, betterment levies, land tax and also lower prices for their output than what they would have got under a free-trade environment. It thus opens up a whole gamut of policies that distort true costs as well as true prices, not only of irrigation water but also of agricultural produce that is being enhanced through irrigation. The very estimation of the DRC of irrigation water would involve getting detailed cost structures of irrigation works, deconstructing the input costs into tradable and non-tradable segments and then valuing tradable inputs at relevant border prices and the non-tradable inputs at their appropriate shadow prices.

In the present paper, focus will however be on the first two approaches.

4 Estimating irrigation subsidies: Net cost to the government approach

As mentioned above, the net cost to the government or subsidy (S) on account of making irrigation water available can be derived by deducting from the gross cost to the government (C), the revenue realized in the form of payments (R) received from the beneficiaries of this water. Thus:

$$S= C-R$$

This is the approach most commonly employed to measure subsidies. While there is no conceptual problem in estimating subsidies following this approach, the three key constituents—cost, beneficiaries and revenue—on which this approach is based need to be clearly defined, identified and understood. In the context of quantifying irrigation subsidies, analysts have interpreted these three terms differently. Depending upon how one defines and evaluates these three underlying concerns, the estimated value of subsidies can vary over a wide range. It is therefore important to have clarity on these three concerns and the methodology to be followed in estimating each of them so that more transparent, uniform and comparable estimates of subsidies to irrigation water can be generated. In the following sections we attempt to do this.

4.1 Cost of irrigation water

The interpretation of the concept of the cost of irrigation water has varied greatly in the literature, depending upon the purpose at hand and the prevailing water availability scenario. Quite often, the cost of making irrigation water available has been equated with the supply cost—that is, the financial costs associated with the provision of water. The financial costs in turn have been equated with either the sum of the capital and O&M costs (however these may have been defined) or, more often, with O&M costs alone, with capital cost treated as a sunk cost. The main purpose in defining and estimating these costs has been to provide a basis for fixing water tariffs. The tariffs so determined are expected to help recover the financial costs of irrigation water provision from farmers and, thereby, in moving towards attaining the financial sustainability of the irrigation projects. In practice, however, this information is rarely utilized for the fixation of tariffs, which are generally fixed on socio-political rather than strictly economic considerations. The tariffs so fixed have therefore often differed widely from the actual financial costs of irrigation water provision. Even these low tariffs are seldom recovered in full, often leading to insufficient maintenance and, ultimately, to financial unsustainability of irrigation projects.

Notwithstanding the utility or otherwise of the estimated financial cost of irrigation water provision as a basis for fixing tariffs, attempting to equate the cost of irrigation water with the financial cost of making this water available is beset with problems. Such an approach implicitly assumes that water is a free gift of nature, it is available in abundance, there are no competing uses for irrigation water, and its use for irrigation assumes no social, economic or environmental externalities. In situations where the water is a constraining factor with competing uses, irrigation water supply is associated with a wide range of intermediate costs in addition to those purely associated with private or social spheres (OECD, 2002).

Thus making water available for a specific use, at the cost of other competing uses, say industry, requires accounting for the opportunity cost of water. Further, water diverted and used for irrigation often causes environmental externalities and degrades natural resources. From such a perspective, the costs of these externalities need to be considered while determining the cost of irrigation water. Thus the social cost of water supply is not just the cost of the goods and services that are required in order to make the water available for use, but also the costs that society has to bear in terms of reduced opportunities of using water resources in alternative ways and the costs that are necessary for maintaining and improving the quality and quantity of the water capital up to a level that is considered sufficient for long-term sustainability (Massaruto, 2002).

4.1.1 Water as an economic good

With growing sectoral, seasonal, regional or aggregate water scarcity in large parts of the world, emerging competing demands for irrigation, drinking, industry and environment—coupled with growing concern about water-related environmental pollution and resource depletion and degradation—realization about the need for treating water as an economic good rather than a free gift of nature has, of late, started to emerge. It is being increasingly emphasized that managing water as an economic good has the potential to achieve efficient and equitable use, and to encourage conservation and protection of water resources.

The formal concern and debate on these issues came into focus with the International Conference on Water and the Environment (ICWE, 1992) which emphasized that the failure to recognize the value of water has led to environmentally damaging uses of the resource. This is a contributing factor in the development of the 1992 Dublin Principles, a set of principles attempting to concisely state the main issues and thrust of water management. The principles state that "Water has an economic value in all its competing uses and should be recognized as an economic good."[3] Agenda 21 and the Dublin Principles thus put the concept of water as an economic good on the global agenda, and this concept over the years has received wide acceptance by the world's water professionals, though initially there was substantial confusion, especially to many non-economist water professionals about what is implied by the statement that water is an "economic good" or an "economic and social good." The Second World Water Forum (The Hague, March 2000) also stressed that decisions on water allocation among competing uses require a better analysis of the value of water (SWWF, 2000). The economic literature has extensively discussed the meaning of treating water as an economic good (Briscoe, 1996; Perry *et al.*, 1997; and Rogers *et al.*, 2002). Several other authors have used an approach similar to that described above (compare, for example, Bazza and Ahmad, 2002; Bosworth *et al.*, 2002; Hellergers, 2002; UN, 1997).

Treating water as an economic good[4] means that, when water is scarce, allocation decisions should take account of the benefits to each user (or uses), the costs of service provision and foregone benefits to users (or uses) that do not have access to water. Such considerations should improve the allocation of water on the basis of trade-offs that have financial, economic, socio-economic or environmental implications for those directly concerned, as well as society more generally. More recent literature and recommendations of international conferences confront the problems of competition for scarce water and shortage of funds for maintenance of irrigation facilities.

The current rationale for treating water as an economic good—using economic instruments to encourage water savings and to generate revenues—apparently addresses problems with effective resource management as well as

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[3] Dublin Principles taken from the Global Water Partnership Web site, accessed on 14 April 2008, from http://www.gwpforum.org/servlet/PSP?iNodeID=1345

[4] A study by the Organisation for Economic Co-operation and Development (OECD) further distinguishes between different levels of supply costs (OECD, 2002). It defines four cost types: private costs; district costs; state or water authority costs; and social costs. Private costs are the costs that are entirely borne by the irrigator. They may include items like energy, equipment and investment costs. In the case of groundwater irrigation from privately owned wells, private costs usually equal full supply costs. Irrigation district costs are water supply costs associated with serving exclusively a clearly identified set of farmers. Different irrigation districts usually face different costs of water supply, depending on the extent of water scarcity suffered in each area. State or water authority costs are referred to as O&M costs originating from multiple-use supply systems owned by the state or a government agency, as well as the financial and investment costs associated with the construction of these systems. Social costs constitute the fourth cost level and include opportunity costs and externalities.

problems with sustainable financial management (Hellegers and Perry, 2004). Thus, treating water as an economic good is about making the right choices,[5] and not necessarily about setting the appropriate price for water (Savenije, 2000). Nor does it necessarily mean that water should be allocated by market prices (Perry *et al.*, 1997). Thus, while consensus seems to exist about the efficacy of treating water as an economic good in improving allocative efficiency, the international debate on the feasibility of using it as a basis for full cost recovery is far from over. At the operational level, and even at the policy level, however, there is still confusion about the potential role of economics in improving water management in general, and irrigation management in particular.

The two basic concerns in treating water as an economic good are: what is the cost of supply of water?; and what is the value that is derived from use of this water? Notwithstanding the apprehensions about the role and efficacy of treating water as an economic good in bringing about improved and more efficient water management, it is however important to establish what it costs to provide water services, or for that mater any service that is subject to a charge. This is irrespective of the intention of the water-supplying agency to recover fully or partially the cost of provision of this service.

Even if the full cost of provision is not intended to be recovered,[6] determining the cost of the service will make the extent of the subsidy being provided to the user more clear and transparent. In the following sections, the paper defines the various cost concepts associated with the provision of water and in the process defines what is meant by the "full cost" of providing water.

4.1.2 Cost of water provision

Following Rogers *et al.* (1998) we distinguish three cost concepts—the full supply cost, the full economic cost and the full (social) cost. The compositions of the various components that add up to make the different costs are presented schematically in Figure 4.1. Each of these is explained below in brief.

4.1.2.1 Full supply cost

The full supply cost includes the costs associated with the supply of water to a consumer without consideration of either the externalities imposed upon others or of the alternate uses of the water. Full accounting costs thus are composed of two separate items: O&M costs; and capital charges.

O&M COSTS: These costs are associated with the daily running of the supply system. Typical costs include purchased raw water, electricity for pumping, labour, repair materials, and input cost for managing and operating storage, distribution and treatment plants. In practice, there is typically little dispute as to what are considered O&M costs and how they are to be measured.

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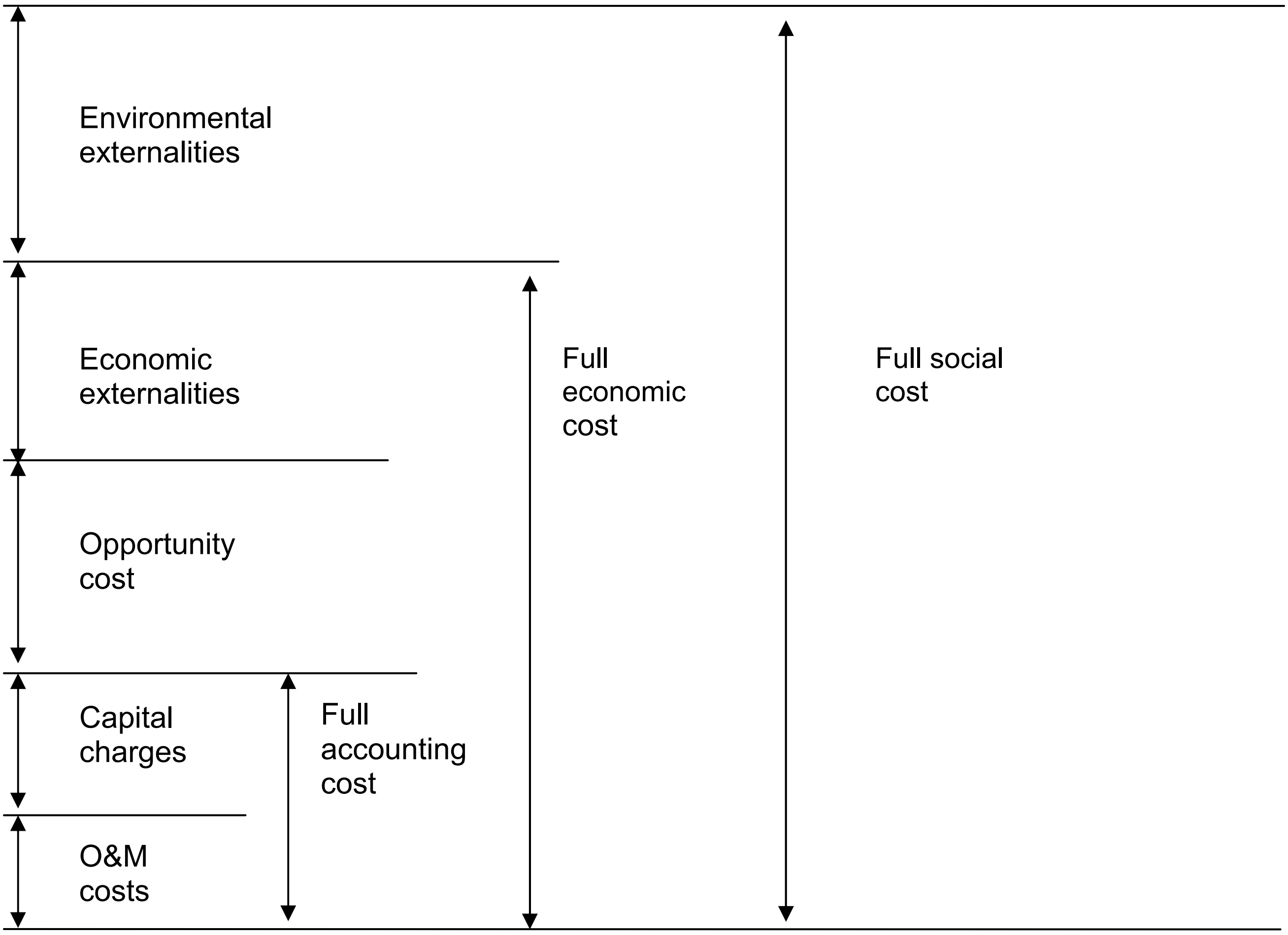
[5] It has also been opined that the economic efficiency criterion is only one of the basic principles for making socio-economic trade-off analysis. The criterion of efficiency is attractive to economists because it carries little ethical content. There is, however, no reason to believe that resource allocations are socially desirable just because they are efficient. Optimality can only be assessed in terms of social welfare, which is only meaningful if there are agreed ethical principles. An optimal arrangement is efficient, but an efficient arrangement is not necessarily an optimal one since other criteria, such as social equity and ecological sustainability, also may play a role (Hellegers, 2002).

[6] The European Water Framework Directive (WFD), as well as many institutional documents (such as those from the World Bank and the OECD), emphasize the importance of achieving full cost recovery of water. Yet the very concept of "full cost recovery„" despite its apparent clarity, is ambiguous and can generate confusion. International comparisons must often contend with varying interpretations of this concept (Massaruto, 2002).

CAPITAL CHARGES: These include capital consumption (depreciation charges)[7] and interest costs associated with reservoirs, treatment plants, and conveyance and distribution systems.

Figure 4.1 General principles for cost and value of water



Source: Adapted from Rogers *et al.*, 1998.

There are some disagreements about the calculation of capital charges. While older methods use a backward-looking accounting stance and look for the costs associated with repaying the historical stream of investments, modern methods stress a forward-looking accounting stance and look for the costs associated with replacement of the capital stock with increasing marginal costs supplies. These coupled with the O&M costs approximate the long-term marginal costs. The paper elaborates on these subsequently.

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[7] Depreciation charges refer to the consumption of fixed assets over time in a way that reflects their reducing value.

4.1.2.2 Full economic cost

The full economic cost of water is the sum of the full supply cost as described above, the opportunity cost associated with the alternate use of the same water resource, and the economic (pecuniary) externalities imposed upon others due to the consumption of water by a specific actor.

OPPORTUNITY COST: This cost addresses the fact that by consuming water, the user is depriving another user of the water. If that other user has a higher value for the water, then there are some opportunity costs experienced by society due to this misallocation of resources. The opportunity cost of water is zero only when there is no alternative use—that is, no shortage of water. Ignoring the opportunity cost undervalues water, leads to under-investing in water conservation and causes serious misallocations of resources among users.

ECONOMIC (PECUNIARY) EXTERNALITIES: As a fugitive resource, water results in pervasive externalities. The most common externalities are those associated with the impact of an upstream diversion of water or with the release of pollution on downstream users. There are also externalities due to over-extraction from, or contamination of, common-pool resources such as lakes and underground sources. There may also be production externalities due, for example, to the agricultural production in irrigated areas damaging the markets for upland non-irrigated agriculture, or forcing them to change their inputs. The standard economic approach to externalities is to define the system in such a way as to "internalize the externalities." A distinction has been made between economic and environmental externalities, realizing that in some cases it will be difficult to distinguish exactly between them. The externalities may be positive or negative, and it is important to characterize the situation in a given context and estimate the positive or negative externalities and adjust the full cost by these impacts.

Positive externalities occur, for example, when surface irrigation is both meeting the evapotranspiration needs of crops, and recharging a groundwater aquifer. Irrigation is then effectively providing a "recharge service." However, the net benefit of this service will depend on the overall balance between total recharge (from rainfall and surface irrigation) and the rate of withdrawal of groundwater.

Negative externalities, as discussed in Briscoe (1996), may impose costs on downstream users if the irrigation return flows are saline, or where return flows from towns impose costs on downstream water users. These negative externalities should be borne by the water users who impose these externalities on others.

4.1.2.3 Full (social) cost

The full cost of the consumption of water is the full economic cost, given above, plus the environmental externalities. These costs have to be determined based upon the damages caused, where such data are available, or as additional costs of treatment to return the water to its original quality. See Box 4.1 for a discussion on the relationship between pricing and full cost recovery.

ENVIRONMENTAL EXTERNALITIES: The paper makes a distinction between economic and environmental externalities. The environmental externalities are those associated with public health and ecosystem maintenance. Hence, if pollution causes increased production or consumption costs to downstream users, it is an economic externality, but if it causes public health or ecosystem impacts, then we define it as an environmental externality. Environmental externalities are usually inherently more difficult to assess economically than the economic externalities, but we argue that it is possible, in most cases, to estimate some remediation costs that will give a lower-bound estimate of the economic value of damages.

While theoretical classification of different costs is relatively straightforward, in practice quite often, a clear distinction between the financial costs, environmental costs and resource costs becomes difficult, as there are risks of overlap and even mix-up with the consequence of double counting. As mentioned by Rogers *et al.* (1998), the distinction between economic and environmental externalities is very narrow. Thus, while keeping the spirit and need for accounting of the various costs as defined by them intact, several researchers have often put the economic and environmental externalities into one broad group of irrigation externalities to include such irrigation-induced externalities as waterlogging and soil salinization, point and non-point source pollution associated with the use of fertilizers and pesticides, loss of aquatic habitat, lowering of the water table and the like.

Box 4.1 Relationship between full cost recovery and pricing

Knowing the full cost of water services would bring (among other things) greater transparency in terms of impacts on the environment, the sustainability of the irrigation infrastructure, costs to deliver the service and who should pay (Tardieu, 2004). There appears to be a general consensus that full-cost pricing be promoted and implemented and should form the basis for cost recovery (Cosgrove and Rijberman, 2000). While supportive of the general principle of full-cost pricing, some analysts have, however, raised apprehensions about using it as a basis for cost recovery. It has, for example, been argued that while full cost recovery may prove feasible in developed environments, for example in Australia (Briscoe, 1999), it may prove unrealistic in developing economies with subsistence-oriented smallholder irrigation schemes. This is why, while acknowledging that "the recovery of full cost should be the goal for all water uses," the International Commission on Irrigation and Drainage (ICID) alternatively recommended that in order to achieve sustainability, the full cost of water provision "need not necessarily be charged to the users" (Tardieu, 2005).

Similarly, the Global Water Partnership considers "the recovery of full cost should be the goal for all water uses unless there are compelling reasons for not doing so."[8] In the same way, the European Framework Directive for Water asks for "adequate" pricing of water, leaving room for charging users a lower price than that required for full cost recovery (Tardieu, 2004). Thus using the full-cost principle as a basis for cost determination does not prevent countries from deciding on a level of cost recovery and on the contribution of water users to the recovery of the costs of water services that is below the full cost. The uncovered costs then can be borne by someone—taxpayers or society at large—in the form of subsidies. Though full cost recovery is desirable from the point of the view of long-term ability to finance irrigation and promote more efficient use of resources, problems related to practical implementation need to be kept in view.

Keeping in view the general consensus on treating full-cost accounting as the basis for determining the cost of providing water services for different uses and having defined the various components that make up the full cost, the paper now turns to the estimation of each of these components. The estimation of different components of full cost, is however, not straightforward. The paper deals with the estimation issues in respect of each of these components of the full cost.

4.2 Valuation of capital

The attributable annual cost of capital invested in irrigation infrastructure comprises two components: the annual interest cost; and the annual depreciation. Since these costs are to be calculated on the amount of capital invested, an important question that needs to be resolved is: what is the capital base on which these costs should be calculated? The paper discusses below and in the following Sections 4.2.1 to 4.2.4 the procedure for determining

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[8] Taken from the Global Water Partnership Web site, accessed on 14 April 2008, from www.gwpforum.org/gwp/library/Tacno4.pdf

the value of the capital base which should form the basis for determining the annualized capital cost vis-à-vis the depreciation and interest cost.

Construction of water-resource projects is an ongoing process. Most of the projects constructed decades ago are still in service. This implies that the capital invested in these projects is still yielding benefits, by making water available, and that all the water that is currently being provided by these water-resource structures cannot be attributed to the current capital expenditure alone. Thus, one must carefully take into account the capital invested at different points of time in the past several decades to arrive at a capital base, which should form the basis for estimating the annual cost of capital—interest and depreciation.

Depending on the accounting system in use, it is possible to use various types of valuation methods for existing capital assets:

- On the basis of the historical value—that is, the value of the assets measured at the prices at which they were originally purchased or constructed;
- On the basis of the current value—that is, the value of all assets constructed in the past measured at current prices. This is computed by multiplying the value of the asset at historical value by an inflation index; and
- On the basis of the replacement value—that is, the present value of an asset on the basis of the current cost of replacing it for an identical service level.

Theoretically, all three methods can be employed to estimate the capital base on which annualized capital cost can be computed. However, each has its own advantages and disadvantages. Because of inflation, evaluating asset value at historical prices often bears no relation to what it would actually cost today to replace those assets. And the longer ago that the asset was created, the less relevant this method of valuation becomes.

The method based on current value raises the question of choice of an appropriate inflation index to compound the historical values of assets to their current prices. The paper reverts back to this issue further below. This method, however, is at a disadvantage because it does not take into account technical progress over time: with improvement in technology, a similar irrigation system might actually cost much less to build today than it would have 20 or 30 years ago.

The third method, replacement value, to a large extent takes care of the issue of cost reduction due to technical progress. In practice it may be difficult and time consuming to apply this to all the capital stock constructed over the years. In addition, in the water sector—being relatively less dynamic than, say, the telecommunication sector—the pace of technical progress may not be as swift as to alter costs in any significant way. On balance, therefore, the current value method appears sufficient and more appropriate than the other two methods for the purpose of estimating the economic cost of assets.

4.2.1 Allocation of joint capital costs

Before addressing the questions related to accounting systems and the choice of valuation methods for the evaluation of capital cost, there is another important issue, relating to multiplicity of use of a number of irrigation structures, which needs to be resolved in the context of determining the capital cost.

An important characteristic of many public utilities is that they provide multiple goods and services simultaneously. Most large water-resource projects have this characteristic, providing at the same time some or all of the following services: irrigation water, municipal water supply, flood protection, hydro-electric power, recreation, navigation, fisheries and so forth. While some of these demands are competitive (such as agricultural and industrial consumption), others are complementary. For example, in some cases releases for agriculture can be passed through turbines to generate power and be used by ships for navigation without detriment to other consumers (Perry, 1986).

In addition to these formally understood multiple purposes for which a project is built, there are several informal uses of the irrigation infrastructure in developing countries which are more difficult to address (Van Koppen *et al.,* 2006). These may include informal diversion and use, such as for livestock, fish culture and small enterprises (e.g., brick making and beer brewing). In Asia, for example, 90 percent of dams for irrigation are multi-purpose (Easter and Liu, 2003). Often, the initial trigger to set up a water project may be one specific factor relating to the control or use of water, yet frequently the combination of factors is such that the achievement of some particular objective may be better promoted by combining other objectives with it. In addition to helping realize the greatest total benefit from the natural resource, the multiple nature of the project also helps makes the project more cost effective, since the sum of marginal costs of each component may be less than the total cost of the project. Thus a multiple-purpose project may be practicable where a single-purpose project may be impracticable.

A problem arises with regard to the basis for allocation of the total cost of the project to its constituent components. Interest in the problem of fair allocation of joint costs in water-resource projects was stimulated during the early days of the Tennessee Valley Authority (TVA) in the 1930s, which had to apportion costs of dam systems among participatory uses. In the literature, various methods have since been suggested for allocating joint costs. Fair cost-allocation concepts have been studied extensively in cooperative game theory, which provides various normative approaches to the problem of allocating joint costs (and benefits) among users by taking the strategic possibilities into account. Some well-known concepts include core (Gillies, 1959) and Shapley value (Shapley, 1953). Since these pioneering studies, several variants and extensions have been developed (see the reviews by Krus and Bronisz, 2000; Monderer and Samet, 2002) and applied to the allocation of costs in joint projects (Young, 1985; Young, 1994).

The traditional methods most commonly used in water-resource planning practices to allocate joint costs are (1) to allocate costs in proportion to some single numerical criterion, such as use, population or level of benefits; or (2) to allocate certain costs (e.g., marginal costs) directly and divide the remainder on the basis of some scheme similar to the first method (Young *et al.,* 1982). Chief among variants of the first method is the use-of-facilities (UOF) method. This method entails that each of the purposes served by one structure, with uses being irrigation, domestic and commercial water supply, be charged in proportion to the capacity (e.g., acre-feet, cubic-feet per second) to which that purpose is entitled. Such a cost-allocation method, however, usually is not efficient.

The fundamental concept of fairness stipulates that for a fair allocation of costs, no user should individually pay more in the joint venture than he would have to pay on his own. This constitutes the minimum incentive for an individual to join. The UOF method however does not promote efficient use of resources in the greatest public interest by assuring a maximum practicable return per dollar invested (Perry, 1986). There are also difficulties in relating consumptive to non-consumptive uses of water (navigation and hydropower, for example). The approach is also highly dependent on disaggregated data, which most irrigation districts or authorities do not automatically generate or retain (Lewis and Hillal, 1995). On the other hand, the transparency of the approach is appealing.

Among the second group of methods, the two main ones are: (1) alternative justifiable expenditures (AJE); and (2) separate costs, remaining benefits (SCRB) methods (Easter and Liu, 2003; Young, *et al.* 1982; Young, 1985). The first approach allocates joint costs based on remaining benefits after subtracting specific costs, where specific costs refer to costs directly attributable to a single purpose (for example, irrigation) and exclude the costs of a change in project design due to the inclusion of a particular purpose.

The second approach, SCRB, is similar to the first one. It assigns costs that serve a “single” purpose to the benefiting purpose, including the costs of any project design changes required to include the added purpose. The remaining “joint” costs are assigned in proportion to the remaining benefits derived for each type of use after subtracting the separable costs (Perry, 1986).

The SCRB approach, which was applied comprehensively in a report by the Irrigation Support Project for Asia and the Near East (ISPAN, 1993), assigns all costs that serve a single need (i.e., a powerhouse only serves the power sector, a lock only serves for navigation) to the benefiting sector. The remaining "joint" costs were assigned in proportion to the benefit derived by each user from that service (for example, costs associated with a navigable canal are allocated to both agriculture and transportation beneficiaries). The SCRB method, as applied in the aforementioned study, ensured that charges to any user must always be less than the benefit derived. The approach thus explicitly deals with competing and complementary demands; and it is transparent, allowing beneficiary groups to understand the underlying assumptions and the derivation of the assigned cost.

However, the SCRB approach is normally more suitable in a planning context, where investments are yet to take place, and options exist to change the configuration of the investment and hence the groups, sectors and areas that will benefit. The application of SCRB to a system that has been in place for many years introduces a number of difficulties. The approach, for example, allows no cost allocation to any user in excess of the cost of the alternative minimum cost solution. In addition, the linkage of cost allocations to benefits derived makes the result sensitive to the time at which the analysis is done.

Thus, of the various methods discussed above, it is necessary to choose rationally the most appropriate method. Apart from some of the considerations discussed above, the choice of the method should take into consideration the simplicity in terms of its practical applicability and computational and informational demands. Of the last two approaches to joint cost allocation, AJE is easier to calculate than SCRB because it relies on specific costs rather than separable costs (Easter and Liu, 2003). To elaborate, specific costs in multi-purpose projects are the project components and costs that are specific to only one purpose, such as the cost of a pipeline to deliver water to a city. Separable costs in multi-purpose projects are the extra costs that are incurred when an additional purpose is added to a multi-purpose project. If irrigation is added as a project purpose, the separable costs would be the cost of the irrigation canals plus the costs of increasing the reservoir capacity. The latter cost is not a specific cost, but it is separable in that the reservoir would be smaller without the irrigation purpose. The separable costs are calculated by comparing project costs with and without each purpose separately

An irrigation project in Andhra Pradesh, India, provides a good example of how the costs of different types of uses or purposes of a multi-purpose project can vary depending upon the method chosen for cost allocation (see Box 4.2).

The main problem in the allocation of joint costs among the various components on the basis of the suggested methods discussed above arise on account of one or more of the following: (1) the non-vendible character of the utilities involved; (2) the intangible[9] nature of the benefits to be conferred; (3) the time factor; and (4) the incidence of benefits. The paper elaborates briefly on these.

Some of the outcomes of a multi-purpose water project are non-vendible—that is to say, they are not forthcoming in a form that renders them readily saleable in the ordinary processes of exchange and therefore the joint costs incurred in the production of these several utilities cannot as a whole be allocated by reference to the operations of a free market. In such circumstances, the allocations can be made on the assessment principle—that is, some public body, endowed with the requisite legal power, must make the allocations and enforce them. The sanctity of this procedure is to be viewed in the general welfare of the social group. The final decision, then, is a social rather than individual one and will be conditioned by the prevailing social preferences of the people to whom the administrative body in question is ultimately responsible.

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[9] Some costs and benefits (such as the scenic beauty) cannot be easily quantified, and others, although they can be quantified, cannot be valued in any market sense (for example, a reduction in lives lost). Such costs and benefits are generally referred to as intangible costs and benefits. These intangibles are obviously important in many cases and have to be considered by decision-makers.

The second important consideration is that not only are many of the public benefits from these projects non-vendible, but they may be of such an intangible character that they cannot be evaluated in monetary terms. One option, which has certain limitations, is to submit the question to the judgment of organized society. How much are the people, acting collectively, willing to pay for these intangible benefits? In addition, there may be instances where both tangible and intangible benefits are derived but the intangibles may outweigh the tangible benefits. Since no two projects are likely to yield the same combination of tangible and intangible values, there can be no general formula appropriate for all cases. The proportion of the joint costs to be handled in this way, however, will vary directly with the variety and extent of the intangible benefits that accrue.

Box 4.2 Alternative cost allocation in three projects in India

Two alternative cost allocations were calculated for the distribution of project costs. The first allocation is based on the quantity of water delivered for each purpose or use. Since the allocation is based on water delivery, only the three consumptive uses are allocated a share of the costs, with between 95 and 98 percent of the cost allocated to irrigation (see Table 4.1). When the costs are allocated based on benefits generated, all five major water uses are allocated costs, and irrigation's share drops to between 88 and 94 percent (see Table 4.2). Thus, in multi-purpose projects, irrigation is likely to be allocated a major share of the costs but, with growing domestic and industrial demand for water, irrigation's share is likely to drop significantly over time. In projects that include an important flood-control component, irrigation's cost-share would drop even more.

Table 4.1 Cost allocation for three consumptive uses based on water delivery (in by percentage)

Water project	Domestic water supply	Industry	Irrigation
Nagarjursagar	2	0	98
Tungabhadra	1	4	95
Sriram Sagar	2	3	95

Table 4.2 Cost allocation among three projects based on benefits (in by percentage)

Purpose or use	Project		
	Sriram Sagar	Nagarjursagar	Tungabhadra
Irrigation	88.1	94.3	91.3
Hydropower	3.0	4.0	4.2
Domestic	3.0	1.6	2.1
Industry	4.3	0.1*	2.3
Fisheries	1.6	0.1 *	0.1

Source: Easter and Liu, 2003.

* Approximately

The consideration of the time factor in joint-project cost allocation in water-resource projects arises on account of the long life of these projects, which often span decades. During the life of the project, social preferences as to how the project should be operated and the purposes they should serve may change, in some cases substantially. Changes in demand, expressed as society's willingness to pay for services provided, may prompt reallocation, ordinarily defined as a change in reservoir operating rules and operational priorities.

Should the allocation of joint costs be made now and in the light of present circumstances, or should it be made on the basis of conditions that may reasonably be expected to prevail in the future? Should that portion of the joint costs to be met from taxation on account of intangible benefits be determined now before the full measure of such benefits has been demonstrated and before public opinion has had an opportunity to experience and evaluate them, or should it be determined by reference to the future? Should some definitive allocation, which will bind coming generations, be made now, or shall present arrangements be regarded as merely tentative and subject to future adjustment?

Assuming water storage to be in most cases fixed by original design, significant questions of fairness and economic efficiency arise with respect to the redistribution of benefits and costs after reallocation. For example, the flood-control component of a project at the time of construction might be relatively insignificant because of the undeveloped condition of the area subject to flood. If, however, the wealth and population of the area increase because of exploitation of its basic resources, flood control may become an issue of major social significance. The attitude of the people toward it would then be completely changed; whereas formerly they would have paid nothing for such protection, they now would be willing to pay considerable sums.

A further difficulty arises in connection with the incidence of benefits. Some benefits are primarily individualized or local, while others are socialized or general. Each particular service provider possesses something of both characteristics, but the combination varies. In flood-control projects a great variety of combinations of local and national interest may occur. In certain cases, such as a large storage reservoir on a tributary stream, there may be no local interest of any significance involved: practically all the benefit will accrue on the main stream, perhaps many miles away. This general benefit will be so diffused that it is impossible to trace its final incidence to any individual interest or to any local community.

Where the benefits are so diffused that their incidence cannot be traced to some individual or community, it is impossible to assess any portion of the joint cost directly to ultimate beneficiaries. Yet this joint cost was in large part incurred for the express purpose of creating these benefits. For this reason, then, they should properly be charged with their proportionate share of the joint cost. Since, however, there is no possibility of recovering from individual beneficiaries the cost assigned to these social utilities, it must be met from public funds, though it may not be the most efficient method.

The previous discussion would thus suggest that it is rather difficult to allocate joint-project costs with any scientific precision. Despite the consideration given to the subject over the years, none of the numerous methods of cost allocation that have been proposed from time to time appear to have gained general acceptance and, as a result, the allocation of joint costs continues to be one of the more controversial issues in the economic analysis of water resource development projects. The complexity of the cost-allocation problem has led some authors to conclude that there is no economically justifiable way to allocate joint costs (Ransmeier, 1942; Thomas, 1974).

The above discussion suggests that a substantial part of the difficulty in cost allocation based on the alternative methods discussed above apparently stems from the significance of "benefits" derived from the project as a basis for the allocation of joint costs and failure to recognize that any such allocations based solely on tangible and direct benefits occurring to first beneficiaries alone may not be consistent with a fair allocation of joint costs. For a fair allocation, one must therefore take into consideration the non-vendible character of the utilities involved, the intangible nature of the benefits, the time factor and the incidence of benefits. Allocation of costs on the basis of tangible benefits alone, and that too occurring only to the first beneficiary, may not be the best approach to adopt.

Keeping in view the methodological problems in estimating these costs and benefits and to steer clear of any controversies on the allocation of joint costs on the basis of benefits emanating from the project, a more realistic solution to the problem of cost allocation could be provided by a modified method based on an attributable-cost method that puts the cost of each service on the respective service for which this was incurred. Once all separable costs such as irrigation canals or navigation locks have been assigned, full account has been taken of all direct relationships between costs and particular services.

The costs for joint facilities, estimated by deducting the attributable costs from the total cost of the project, such as that of multi-purpose reservoirs and dams, could be treated as a general charge upon the public revenue in the same way as other social services are. This solution, while in conflict with the capitalistic tradition, is nevertheless in harmony with the social nature of these undertakings. Such undertakings are considered to be social institutions designed to promote general welfare by supplying a variety of useful services. The joint costs are incurred, neither for any particular benefit, nor for the advantage of any individual or group of individuals, but for the general good. Hence, it is proper that they should be borne by society generally rather than by individual beneficiaries.

To sum up, depending upon how the "joint cost" is envisaged, either the AJE or the attributable-cost method can be employed for allocation of joint costs in the case of multi-purpose irrigation projects.

4.2.2 Bringing capital cost expenditure to a current value: choosing an appropriate inflation index

As discussed earlier, most of the capital costs of irrigation projects are incurred during the years when these projects are under construction. Due to inflation and other factors, the value of capital invested 20 years ago may not be the same as that invested today. Thus $100 invested years ago may have yielded much more benefit than would $100 invested today. It is therefore important to bring the capital invested during different years to some common denominator.

According to ICID guidelines for evaluating the full economic costs of irrigation, presented by Rieu and Gleyses (2003), bringing the capital costs incurred on different projects over a period of time to current-value terms requires data and information on the so-called Public Works Index (PWI), which takes account of inflation and allows for an estimation of the current-value of infrastructure assets. Such an index, while generally available in European countries, is rarely available in developing countries. Under such circumstances, bringing the capital costs incurred in the development of different projects to current-value terms requires the use of some other appropriate index to account for inflation during the period. In the absence of any specific price index for irrigation assets, the general practice has been for analysts to use either the general price index or some sectoral price index.

Some researchers have attempted to build their own indices which more closely approximate the asset valuation of irrigation infrastructure. For example, Gulati and Svendson (1995) have classified the cost of irrigation schemes in India into four broad categories: (a) labour and miscellaneous items not included in other categories; (b) cement; (c) iron and steel; and (d) machinery and transport equipment, assigning expenditure weights of 0.60, 0.20, 0.15 and 0.05 respectively to the four categories. Using separate inflation rates for each of these four categories of investments, they brought the expenses incurred for each of these items to constant prices. By then combining the value of the four categories they arrived at the current values.

While such an approach has some advantages when compared to using a general price index, this method is also not free from complexity. For example, the inflation rate for labour and other miscellaneous-cost items is rather difficult to estimate because of the heterogeneity—not only of skills within the labour component, but also among miscellaneous items. In the absence of information indicating proportions for the various kinds of labour employed in constructing projects, and a lack of data on price indices for different categories of labour, one has to make suitable assumptions to estimate the inflation rate of labour and other miscellaneous-cost items as well as changes in the ratio between labour and capital involved in the construction of the irrigation works. Further, when using a long time series, the temporal behaviour of prices exhibit significant differences and a common inflation rate cannot be applied. Under such circumstances the time series may need to be suitably divided into sub-periods and inflation rates estimated separately for each period, the derived sub-period estimates then being aggregated.

In recognizing the lack of availability of any detailed breakdown of data on cost constituents for different projects, and to keep the process of converting historical value to current value somewhat simpler, wherever available an index similar to the PWI may be used to complete such conversions. In the absence of a PWI or similar index, it may suffice to use a general inflation index.

4.2.3 Treatment of cost of incomplete projects

At any point of time there are some investments that are going into the construction of new projects or the rehabilitation of existing ones. Given the nature of irrigation projects, especially medium- and large-sized projects, construction maybe spread over a long period of time. This could be on account of several factors: constraints on the availability of adequate funds; technological problems; the availability of skilled manpower; or political interference. Thus during the first few years of construction when the capital is being invested, no irrigation potential is created. Following the initial phase, further time may be spent while capital expenditure continues to be made and some potential is realized. It is after some time, with the entire capital invested, that the expected irrigation potential is realized. This gestation period, which can be described as the time between when the project is initiated and the irrigation potential is realized, can vary from project to project depending upon the size, and it can also vary between locations.

On the basis of a detailed survey of 347 irrigation projects in India, it was shown that the gestation period in India is about 12 years (Gulati, Svendsen and Choudhary, 1995). Should the capital invested in such projects—whether they have started yielding benefits or not—be accounted for in estimating the capital base, which is in turn used for calculating the annualized cost of capital? In principle, as in the case of industrial projects where there is a clear concept of commencement of commercial operations, in the case of irrigation projects, because of their special nature, such a clear-cut concept is difficult to adopt. It would therefore support the principle that investments in projects which have been completed and commissioned should enter into calculations for determining the capital base of investments in irrigation (Vaidyanathan, 1992). The use of any arbitrary factor or rule to account for partially completed or ongoing projects being constructed may not be desirable and could be subject to criticism. While it may not be possible to make this classification precisely with the available information, it should be possible to obtain a reasonable approximation through analyzing project-level capital expenditures.

4.2.4 Miscellaneous issues in capital cost determination

Aside from the previously raised points, there are some other issues that affect capital cost determination. The actual costs tend to be inflated by a variety of factors such as time and cost overruns, defects in project design, deficiencies in management, waste and leakage. The extent of this over-capitalization could be 50 percent or more of the efficient cost of construction. Strictly speaking, while it would be proper to adjust for these cost overruns when determining the capital base for calculating annualized costs, in the absence of any objective criteria for quantifying the magnitude of over-capitalization due to these factors, and to avoid any arbitrariness in adjusting these costs to some measure of a fair cost, it would be reasonable not to attempt any adjustment on this account (Vaidyanathan, 1992).

Another question in determining the capital base relates to the treatment of interest paid on capital during the construction phase of the project. Although the interest paid in this context is accounted for and treated as part of the project's capital costs, the general practice has been not to treat the interest as part of the capital invested. However, there may be a case for capitalization of interest paid during construction given the opportunity costs associated with its allocation.

4.3 Annualized capital cost

Having discussed in Sections 4.2.1 to 4.2.4 the modalities for estimating the capital base to be used as the foundation for the computation of the annual cost of capital invested, the paper now describes the process for estimating the annual cost of capital. As discussed earlier, the annualized capital comprises depreciation and interest costs. Below, the paper first deals with the issue of depreciation and then with the interest cost on the capital invested.

4.3.1 Estimation of depreciation

Estimating rates of depreciation requires making suitable assumptions about the life of the project and the method and rate of depreciation.

4.3.1.1 Life of the irrigation project

What should be taken as the life of the irrigation project for the purpose of calculating depreciation? Like any other man-made structure, irrigation projects based on dams or otherwise have a finite life, though the economic life of these structures may span several decades, and often the structures will keep providing a service long after their technical or design life has been surpassed. Dam management around the world is coming to realize that, although dams generally last beyond the lifetimes of the people who have built them, they do not last forever. Dams are subject to life cycles of design, construction, operation, rehabilitation and, finally, decommissioning. On the other hand, projects constructed in more recent years can be expected to last much longer than those constructed some time in the past. This is because of better technology, design and the quality of material used to construct them.

In addition to the factors associated with the design and the construction of a project, its life depends upon several other factors, including the level of attention paid to issues such as sedimentation; the quality, adequacy and regularity of maintenance; the quantity and the quality of water (in areas of acidic water the life of a dam may be much less); the extent of rehabilitation and restoration works undertaken, and so forth. Thus, depending upon these factors, some projects may survive much longer than their designed life, while some may even survive for a shorter time than anticipated. For example, the lifespan of the Tarbela Dam in Pakistan, which was originally projected to be 60 years when it was first completed in 1974, is now expected to be about 80 years (UNEP, 2004).

In the literature reviewed, there are no clear-cut guidelines or methods suggested to estimate the life of irrigation projects. The world over, while the first large dams started to be built even before 1900, the overall rate of large dam construction picked up during the 1950s and generally peaked in different regions of the world during the 1970s and 1980s (based on the information available in the World Commission on Dams [WCD] Report Annex). This implies that most of the dam structures built during this period, if they are still in service, are currently between 20 and 60 years old. Information could not be obtained on how many of the dams that were built during the decades from 1900 onwards were still in use with or without rehabilitation, or which of these have been decommissioned. In the United States, the maximum life of a dam licence is set at 50 years, with provisions for re-licensing. In contrast to large irrigation and multi-purpose projects based on dams, other gravity-based large and medium-sized projects may have different lifespans. The project life of such irrigation projects is generally taken to be 20 to 30 years, but this can be extended to 50 years. Sinha and Bhatia (1982) assumed the project life of the

Auranga irrigation project in Bihar at 50 years. The committee on irrigation water pricing of the Government of India took the average life of an irrigation project at 100 years (Vaidyanathan, 1992). There exists substantial case-study material that indicates the global significance of this issue, but rigorous empirical analysis is still lacking.

Given the heterogeneity of projects in terms of their nature, location and size; year of construction; quality of construction, water and operations; adequacy and regularity of maintenance; and extent of rehabilitation works undertaken, it is difficult to assume a common length of life for all irrigation projects for the purpose of calculating depreciation. Based on these considerations it is suggested, although subjective and arbitrary, to use an average service life of 50 years for medium-sized to large irrigation projects. This is obviously on the conservative side but may not call for any substantial revision since maintenance costs may increase substantially after some time. Some investigations seem to show that different assumptions about lengths of life do not affect the viability of schemes to a significant extent (Foster and Beesley, 1963).

4.3.1.2 Method and rate of depreciation

Depreciation is an important concept in the long-term management of assets, since it addresses the issue of asset replacement at the end of an asset's service life. The most accurate method for determining annual depreciation is the "utilization method" whereby the depreciation is calculated according to the usage of the asset in a given year. The more the asset is used, the larger the value of depreciation. The application of such a criterion for the evaluation of annual depreciation for irrigation projects is generally difficult due to the non-availability of information regarding annual usage. As a result, the straight-line method, which suggests the use of linear depreciation following the service life of the asset, is generally used to evaluate depreciation. Thus, adopting 50 years as the useful life of a project gives an annual depreciation of two percent of the original value. Depreciation calculated in this way is obviously sensitive to the life cycle assigned to the project.

4.3.2 Accounting for the interest on capital invested

There are alternative ways in which the interest cost of capital can be accounted for. One way of computing the interest cost is to charge the interest on the book value (at historical prices) of the project at interest rates actually prevailing in the past when the capital borrowing took place. Another way could be to evaluate interest at current borrowing rates without evaluating the capital at current prices. The question that needs to be resolved is what borrowing rate should be used for evaluating the cost of capital.

Funds for most irrigation projects, especially in the past, were for the most part funded either out of budgetary allocations, through grants and loans at concessional or nominal rates of interest from central governments to state governments, or through loans or bonds raised by the state governments or their agencies. However, the loans or bonds issued by the state to raise money in most cases were not specifically meant for the purpose of irrigation, but formed the general pool of state borrowing. As such it is not generally possible to relate particular loans to any specific uses. These borrowings carry different maturity periods with varying interest rates and as such it is difficult to identify a unique interest rate for borrowing for irrigation investments. In more recent times, there has been increased project, or state-specific, funding from international lending institutions such as the World Bank and the Asian Development Bank.

While some of the lending from these international donor and lending institutions is provided in the form of grants, the rest may not carry the burden of any interest (such as International Development Association grants from the World Bank to developing countries) or are charged interest costs which are generally much below the cost of borrowing from commercial financial institutions. Given these complexities on the different timings during which such funds are raised, the basket of sources which constitute these funds, the length of timing for which the funds are raised, and the differential interest rates at which the funds are borrowed during different periods, it is difficult to assign a unique interest rate which could be used to evaluate the cost of borrowings. Thus taking into account the specific but complicated traits of financing of irrigation infrastructure, a preferable and certainly simpler approach would be to assess interest costs uniformly on a middle-of-the-road basis, such as the average interest rate paid on the outstanding public debt by the state or the average yield on a Negotiable Certificate of Deposit.

4.4 Operations and maintenance costs

Operations costs refer to the costs associated with the operation of a system and include such items as staff costs, management costs and electricity for water pumping. Maintenance costs refer to the expenses incurred on actual maintenance of the irrigation system to keep it in working order. Maintenance and renewal costs thus are the costs of maintaining assets in order to provide a good service until the end of their useful life. Given that many water-related assets have extended operational lives and some of them may be buried in the ground or under water, it might be difficult to estimate the appropriate level of maintenance costs needed to operate the assets without their deterioration. The major cause of non-sustainability is the usual but incorrect assumption of saving on maintenance costs at the expense of long-term sustainability.

O&M costs are based on the running costs entered in the project accounts for any given year. While some countries keep separate accounts for operations and maintenance, often the two are put together as O&M costs in public-accounting systems. Procedures for estimating annualized O&M costs are, however, different from those employed in the case of estimating capital costs. Unlike in the case of capital-cost estimation where one has to account for the capital invested in the past to estimate the annualized capital cost of the irrigation infrastructure, the estimation of O&M costs is relatively straightforward and they are measured by the costs incurred during the year of reference only.

There are, however, serious questions that can arise that relate to the adequacy and availability of funds for O&M costs and the efficiency of their use. For example, public-sector irrigation agencies are typically overstaffed and most of the funds allocated for O&M activities go towards paying the salaries of staff, leaving very little money for the actual maintenance of the system. Further, as corruption is a factor in these institutions, the actual remaining money spent on maintenance may be less still, thereby affecting the quality of the maintenance provided which ultimately gets reflected in the quality of service provided to the users and the willingness of the users to pay for the service. While it may be desirable to use some measure of "efficient" cost for operations and maintenance, it may be difficult to define a uniform measure, because of the differences in underlying conditions such as the nature, size, location and age of the project; the quality of construction; and the nature of the institution operating and maintaining the project (Vaidyanathan, 1992).

While the estimation of O&M costs would appear to be straightforward, in practice this may not always be the case. Sound data recording and bookkeeping for O&M are of crucial importance in irrigation (Tiercelin, 1998). Lack of availability of proper disaggregated records often hampers estimation of these costs. Further complicating their evaluation, if the responsibilities are being shared by more than one agency, such as public-sector agencies and Water Users Associations (WUAs), the record-keeping of the latter may not be adequate and appropriate for subsidy estimation. Further, evaluating maintenance costs may be complicated if certain prevailing practices implying no financial transaction (for example, cleaning or clearing of canals by farmers themselves) have to be considered. The maintenance issue becomes crucial since WUAs will have to cover these costs, via a monetary or labour-based contribution by farmers, especially in view of the past tendency to curtail such contributions. The simple fact that different entities may ultimately cover capital costs on the one hand (the public sector), and O&M costs on the other hand (mostly farmers through a WUA, and possibly other users) generates some complications. Nevertheless, if data on the O&M cost of the systems is available, the computation of O&M costs is relatively straightforward in comparison to the estimation of annualized capital cost.

4.5 Cost of providing irrigation water through groundwater-based systems

Alternate measures for the cost of making water available, which were discussed earlier in the paper, are often generally better understood in the context of surface-water-based supply systems. While cost concepts in the case of groundwater-based systems remain broadly similar to the ones defined for surface-water systems, due to some basic differences in the nature of the two systems, the implications and approach in measuring some of the costs vary.

Large surface-water-based irrigation water systems and small groundwater-based irrigation systems are fundamentally different in respect to the size of the command area; the pattern of ownership and operation; number of users of water; the capital and operating costs of the systems and the incidence of these costs; and the system of financing and sources of funds for the purpose. While surface-water-based irrigation systems are generally owned—and frequently operated and maintained—by public agencies, most groundwater-based irrigation systems—based on extraction of water through open wells, dug wells or tube wells—are owned, operated and maintained by individual farmers or an irrigation cooperative.

An advantage of groundwater-based systems is that the farmers themselves enjoy complete control over the system in terms of the quantity of water extracted and the timing of extraction according to availability, and they do not have to grapple with the water-allocation problems between different users and uses that are frequently associated with a surface-water-based system. Consequently, the water-use efficiency and irrigation intensity of a groundwater-based-system is much higher in contrast to surface-water-based systems. The other notable difference between the two systems is that, for surface-based-systems, which require huge amounts of financial resources upfront for construction, individual groundwater-based systems require comparatively miniscule levels of investment and are often funded from either the farmer's own savings or through small loans. The gestation period in the case of groundwater systems is very small and the benefits of investment start flowing almost immediately, while the surface-water-based systems take a long time to construct, consequently yielding the benefits later.

However, groundwater and surface waters are not strictly independent of each other and form part of the same hydrological system. Surface-water systems often act as an important source of groundwater recharge. Unlike in the case of surface-water-based systems, which are generally associated with large environmental and ecological impacts, impacts of groundwater-based systems are usually less. Another important distinctive feature of groundwater-based systems is that they are single-purpose systems; in contrast, surface water-based systems are more often multi-purpose in nature, thus creating the need for devising procedures for allocating joint costs.

In the context of comparing the cost of providing irrigation water from large surface-water-based systems and small groundwater-based systems, the important difference is, in the case of large surface-water systems, that capital costs are generally incurred by public agencies (generally governments) who also own the system, while the O&M costs are either borne fully by these agencies themselves or are partly shared with the water users. Since the costs are incurred by public agencies, these must be recovered from the users of the water. In the case of groundwater-based systems, the capital costs are incurred by individuals who also own the system with the maintenance costs also borne by the owner-operator. The government often does not provide any upfront subsidy towards the installation cost of tube wells. While most of the finances required for meeting the capital and operating costs of groundwater systems are incurred by farmers themselves, the government may sometimes provide loans at concessional rates of interest for this purpose. This support is, however, often too meagre to warrant any consideration. Unlike surface-water systems, where there are a number of users from whom the capital and operating costs are recovered, in the case of groundwater systems there is often only one user, who is also the owner.

Thus, while the capital and maintenance costs of tube wells are typically self-supported by the farmers, the electricity required to operate these wells needs to be purchased. Most of these electricity suppliers until recently were owned and operated by governments or their agencies, and therefore the governments had full control in setting tariffs. Following power-sector reforms in a number of countries, some of these operations have been given to the private sector, and the role of setting electricity prices has been given to a regulating body. Governments still, however, have the liberty to supply power to any sector at a price lower than that fixed by the regulator and to compensate the utility for the financial loss associated with this policy. In the case of such groundwater-based systems, the cost to the government of making irrigation water available is the cost of electricity for pumping irrigation water. Additionally, in those countries or locations where the government may impose groundwater user charges, these charges would also add up to the cost of making irrigation water available through groundwater extraction.

4.6 Opportunity cost of irrigation water

The marginal returns of water, or the value of water, vary across time and space, and across and even within different water-using sectors. Irrigation water, for example, has a very high value at certain times of the year, such as at certain critical crop growth stages, as compared with other periods. The value of irrigation water also depends upon the type of crops grown in an area; for example, it would be higher in a region growing fruits and vegetables than in an area growing fodder or low-value cereal crops.

In a region with an acute scarcity of irrigation water, even at the individual farm level the value of irrigation water will vary depending upon whether the available fixed quantity of water is used to grow water-intensive crops on one hectare of land, for example, or grow less water-intensive crops on three hectares of land. Similarly, the value of water would be high in the hydropower, industrial, commercial and residential sectors (and certain environmental sectors) compared with many uses in the agricultural sector. If water is allocated a low value and is utilized for agriculture at the expense of high-value uses, the lost opportunity resulting from the misallocation of water represents an economic cost to society. Thus, if water is currently used in the agricultural sector, the opportunity cost—i.e., the value of the best alternative use—may be 10 times higher or even more (Briscoe, 1996).

4.6.1 Problems associated with estimation of opportunity cost of irrigation water

Irrigation is the predominant use of water in a majority of the world's river basins, accounting for sometimes as much as 80 to 90 percent of total use. If all water used for low-value irrigation were to be transferred to high-value sectors of the economy, these sectors would not be able to utilize more than a fraction of the water due to their more limited water demand. As a result, the opportunity cost of water would apply only to a small proportion of the total volume of water used in agriculture (Hussein, 2004; Briscoe, 1997).Thus, after the water demands for other sectors or users have been met, the opportunity cost of irrigation water would be zero (or close to it, depending on the ecosystem's demand for water).

Briscoe (1996) opines that opportunity costs estimated in this way are crude and inexact, and depend on factors such as use, location, season, time, quality and reliability of supply. The estimated opportunity cost is thus subject to "location and hydraulic connection possible between users" (Briscoe, 1996). Rogers *et al.* (1998) also acknowledge that the opportunity cost of water used in irrigation would depend on the opportunities and costs of transferring the water among potential users (which will potentially include other farmers, towns and industries). Under these situations, the best alternative use "must consider location and hydrological connections between users as well as the costs of transfer." Further, the opportunity cost of water used in irrigation will decline quickly after all the cost-effective possibilities of water transfer have been exhausted. The opportunity cost of irrigation water may therefore be only half or less than the best alternative use (Rogers *et al.,* 1997).

Another problem with estimating the opportunity cost of irrigation water relates to the reliability of supply and water quality. A lower reliability of supply is acceptable for irrigated agriculture but not for urban water supply. A storage dam yielding *X* cubic metres (m^3) of water supplied to irrigation at 80 percent reliability may yield only 0.5*X* cubic metres (or less depending upon hydrology) for urban water supply at 95 percent reliability. The effective opportunity cost of water used for irrigation should therefore again be halved. Similarly, the quality required for domestic or even industrial uses is much higher than for irrigation. The resulting opportunity cost may therefore be only a fraction of what some economists estimate it to be.

To add to the complexity, the opportunity cost of irrigation water—measured in pure financial terms—may not include some important non-financial considerations. To illustrate this, consider two water-constrained farmers, one of whom grows flowers that generate $1 per m^3 while the other grows rice, generating $0.1 per m^3. Based purely on financial considerations of opportunity costs, all water used by the second farmer should have been used by the first farmer for the cultivation of flowers. But a closer examination of the situation might reveal that basing decisions purely on the financial considerations linked to opportunity costs may not be appropriate in the light of the following (Hellegers, 2002; Perry, 1986):

- The rice produced by the low-productivity farmer was helping keep the price of basic foodstuffs down for the poor;
- The water used by both farmers was pumped from a river where the estuary was being damaged by insufficient flows; and
- The high productivity farmer was using pesticides that harmed fish and thus the incomes of local fishermen.

These hypothetical possibilities raise issues of low consumer prices, food security, income distribution, environmental damage, third-party impacts and social issues in the determination of opportunity cost.

4.6.2 Estimation of opportunity cost

If efficient water markets exist and are functioning, the market price for water can provide a reasonable estimate for the opportunity cost of water. Given that properly functioning water markets are unusual, several alternative methods have been suggested in the literature for estimating the opportunity cost of irrigation water allocation. However, such estimates—apart from being situation specific and devoid of any generalization—also lack rigorous methodological underpinning. Frequently even the minimum basic data needed to make such estimations are not available.

For example one of the possible ways of deriving the opportunity cost of water in agriculture would be to estimate it on the basis of the weighted average of the value-in-use in different sub-sectors (weighted by volume). For example, in the Subernekha river basin in India, the estimated annual demands are 1,346 million cubic metres (MCM) for irrigation, 440 MCM for industry and 235 MCM for domestic users. Assuming that the entire volume of irrigation water could be transferred to industry and domestic sectors, the opportunity cost for about 50 percent of the water used in irrigation would be zero. Using these volumes and estimates of value-in-use in the industrial and domestic sectors, the opportunity cost of irrigation water is calculated as $0.595 per cubic meter.

This figure is much lower than the average value of water used in the industrial sector. This figure is based on the assumption that as much as 440 MCM of water could be transferred out of agriculture without incurring much of the additional cost as estimated here (Sinha and Bhatia, 1982). While this illustration provides an approach to estimating crudely the opportunity cost of irrigation water, in practice it is difficult to obtain such information with a fair degree of accuracy at all sites and all periods of time.

A more appropriate approach to estimating the opportunity cost of irrigation water is to use a systems approach that takes into consideration the supply of water, the demand for water from different users during different periods of the year, and the value of water in different sectors simultaneously. Given that it is often difficult to get precise data on these parameters, one often has to make a number of assumptions about the real impacts and responses of these variables (Briscoe, 1996). In one of the studies using a systems approach, a model was developed for the Columbia River Basin in the north-western United States, and the opportunity cost of water diverted to irrigation estimated by assessing the losses of revenue to hydro-electric power operators (Gibbons, 1986, as quoted in Briscoe, 1996).

No study was found that attempted to estimate comprehensively the opportunity cost of irrigation water using a systems approach, taking into consideration competing demands from domestic, industry and environmental sectors, and incorporating the time dimension of water demand and supply. However, a recent study (Bhatia *et al.*, 2006) attempted to provide an estimate of economic gains to society of moving away from command-and-control water allocation policies that favour irrigation, towards flexible allocation mechanisms that facilitate the voluntary movement of water from low- to high-value uses. The study carried out in the Indian state of Tamil Nadu—a state in the grip of a severe water crisis—addresses the question of whether such a change in allocation policies is worthwhile. It does so by developing optimization models for each of the 17 river basins in Tamil Nadu, including an assessment of the economic value of water in different end-uses: agriculture, domestic requirements and industry. An input–output model, embedded in a Social Accounting Matrix (SAM), is then used to assess the impact of these changes on the state economy and on different rural and urban employment groups.

While the estimates derived from this study cannot be strictly equated with the opportunity cost of irrigation water, the results do provide an estimate of gains to the society if water from irrigation were allowed to move to high-value sectors to overcome their water shortages. The results suggest that a shift to a flexible water allocation system would bring major economic, environmental and social benefits. Compared with the current "fixed sectoral allocation" policy, a flexible allocation policy could, by 2020, result in a 20-percent-higher state income—with all strata, rich and poor, benefiting similarly, with the important exception of agricultural labourers.

Given the complexities of extreme spatial and temporal variability and the difficulty of disaggregating multiple alternative uses in the evaluation, obtaining precise information concerning opportunity costs of irrigation water has proven to be difficult. Even sophisticated research studies cannot estimate them in a way that is universally accepted (ICID, 1997). It has therefore been suggested that while it is important to appreciate the concept of opportunity cost in practice, the decision on precisely what values to incorporate in a cost calculation may be political rather than economic. From a conceptual, practical and political perspective, the appropriate approach for ensuring that the scarcity value of water is transmitted to users is to clarify property rights and to facilitate the leasing and trading of these rights (Briscoe, 1997).

4.7 Opportunity cost of electricity

In addition to water scarcity, many developing countries also face energy scarcities. The electricity supply in these countries is often erratic with long hours of outages. As a result, the electricity used in a low-productivity agricultural sector has a huge opportunity cost in terms of the value of production lost in more productive sectors. Some of these countries are dependent significantly on groundwater for meeting their irrigation water requirements. Given the political compulsions, electricity supply to irrigation is often given priority over other sectors of the economy. In those economies where electricity needs for irrigation pumping are significant, such a prioritization of electricity for irrigation over industry is bound to have significant opportunity costs. In north-west India, for example, electricity consumption in the agricultural sector accounts for more than 40 percent of total electricity consumption. The electricity supply to agriculture is being provided at the cost of industry, which either has to shut down during the non-availability of power or has to invest in alternative sources of energy, such as diesel power generators, or invest in a dedicated power plant. Though we could not find any studies that have tried to estimate the opportunity cost of electricity, we believe it should be far easier to calculate than estimating the opportunity cost of irrigation water. There is a need to quantify the opportunity cost of electricity supplied for irrigation and account for this in the overall cost of irrigation water.

4.8 Resource cost

The resource cost of water can be defined in two ways. The first relates to the scarcity of the resource and its sub-optimal allocation between different uses, in the sense that the cost represents the foregone values of alternative uses of irrigation water. Some researchers have gone a step further and have opined that the resource cost is identified when the economic benefits are forgone, not only due to an inefficient distribution of water resources among different water uses (such as abstraction, discharge and recreation), but also due to an inefficient allocation of water-use permits (abstraction and discharge) based on a given set of environmental standards. This concept is more relevant to a situation when the upstream storage is included in the water service. This definition of resource cost is, however, akin to the opportunity cost of water as discussed above, and thus has already been taken in to account.

The second concept of resource cost is often used in the context of groundwater. Irrigation water provision is associated with both positive and negative impacts on resource cost. The positive economic externality occurs when irrigation is providing a recharge service to groundwater. Thus under conditions where groundwater is being mined, that is groundwater extraction is higher than the recharge process, the recharge from a surface system provides a net benefit that will be equal to the value of the net additional crop output attributable to this additional volume of water (Malik and Faeth, 1992). When the total recharge is greater than total withdrawal (but still does not result in a higher groundwater table), the net benefit from the “recharge service” will be equal to the reduction in the cost of water pumping. This savings in cost may be small (equal to the cost of fuel or electricity) if it does not result in significant savings in investment costs as a result of a higher groundwater table. When the total recharge is much greater than the total withdrawal and results in raising of the groundwater table, this results in conditions of waterlogging and a reduction in agricultural production on the waterlogged soils. This will be discussed further below.

4.9 Environmental externalities and costs

Identifying environmental externalities of irrigation, evaluating their impacts and accounting for these impacts in the costing of irrigation water is a complex undertaking. We begin by briefly describing the environmental effects of irrigation water and their consequences.

Environmental effects associated with irrigation water are multifarious. Such effects can be simplified and considered in two modules. Some of the irrigation-induced environmental effects are linked with the provision of irrigation water by those responsible for the irrigation infrastructure. Examples include faulty design, poor quality of construction, inadequate maintenance, improper water management and lack of drainage. Others may arise as a result of the use of irrigation water and the associated cultivation practices followed by the farmers: the nature of crop cultivated, soil conditions, intensity of irrigation and method of irrigation used. Some other externalities may be caused by factors that are beyond the control of either the providers or the users of irrigation water. A few of the impacts are unpredictable and not very well documented such as effect of irrigation on carbon dioxide and methane fluxes. Further, while some environmental impacts are site or project-specific, others are more general in nature and spread over a wide geographic area. Some effects are felt in the short run, while others appear only in the medium to long term.

The environmental effects of irrigation can be positive or negative. On the positive side, reservoirs created for irrigation provide fresh water for birds and other fauna, fisheries, recreation and tourism. Terraces for growing rice can help slow run-off and reduce erosion. Water management for agricultural purposes can replenish the water table and stabilize river levels. Irrigation canals allow the recycling of urban wastewaters from households and industry. In some locations, irrigation also helps in the management of risks, such as flooding, or those associated with crop losses as a result of periodic drought.

On the other hand, the diversion of water for agriculture has often contributed to environmental problems and the degradation of natural resources. Dams, by reducing natural variability in stream flow, alter the seasonal cycles of aquatic and riparian plants and animals. Reduced stream flows and excessive use of groundwater aquifers lead to higher concentrations of pollutants. Excessive extraction can lower water tables, leading, in some cases, to ground subsidence and, in some coastal areas, to salt-water intrusion. Unsustainable abstractions can also reduce river flows, degrade water quality and harm aquatic fauna. Because irrigation water almost always contains much higher concentrations of dissolved salts than rainwater, its discharge often raises the proportion of salts in the bodies of water into which it flows. Where drainage is inadequate, salt encrustation or waterlogging (the over-saturation of soils with water) can occur.

There are a number of other adverse impacts associated generally with the use of irrigation water. These include surface and groundwater pollution from nutrients and pesticides used in crop cultivation, intensive forms of irrigated agriculture displacing formerly high-value semi-natural ecosystems and affecting biodiversity, increased erosion of cultivated soils on slopes and large-scale water transfers associated with irrigation projects.

The paper briefly describes below the consequences of some of the more significant environmental effects associated with the provision and use of irrigation water.

4.9.1 Consequences of environmental effects of irrigation water

Salinization leads to reduced productivity or even a complete loss of productivity. Global estimates of the total geographical area affected by extreme salinity vary considerably. Some of the available estimates suggest that around 20 percent of the world's irrigated acreage—or about two percent of total agricultural land—is affected by salinization (World Watch Institute, 2000). Some other estimates on irrigation-induced salinity suggest that about 20–30 million hectares are severely affected by salinity and an additional 60–80 million hectares are affected to some extent. Estimates of the area affected have ranged from 10 to 48 percent of the world's total irrigated area. In the late 1980s, roughly 30–46 million hectares were estimated to be in a poor state due to salinization (FAO, 1990; Umali, 1993; Barrow, 1991).

Salinization carries a big price tag. Mexico's grain production is falling by a million tonnes per year because of soil salinity—enough grain to feed five million people. Pakistan today spends more on pumping out salt-laden water than on irrigation. And there is a historical cost as well—illustrated by the fact that perhaps a fifth of the arable land in present-day Iraq has been permanently destroyed due to high salinity (de Moor and Calamai, 1997). In places such as the Iberian Peninsula, Australia and western North America, fertile lands have been abandoned due to salt encrustation, nullifying some of the production gains that irrigation was intended to yield.

Waterlogging occurs when water cannot penetrate deeper down into the soil due to saturation with water. Like salinization, waterlogging is also associated with excessive irrigation of poorly drained soils. Waterlogging also causes a reduction in crop yields. It is estimated that around 10 percent of the world's irrigated land is suffering from conditions of waterlogging.

Groundwater over-pumping occurs when excess pumping depletes the resource capital, as opposed to pumping only what the hydrological cycle will naturally replenish (like living off the interest of a bank deposit). Not only does this abuse permanently reduce the available water supply, it can also lead to land subsidence and waterlogged soil, and increased erosion. It is a global phenomenon. Aquifer depletion in North Africa currently amounts to 10 cubic kilometres of water a year. Water tables in India and China have also fallen sharply. In the western Indian state of Gujarat, over-pumping in coastal areas has caused saltwater to invade the aquifer, contaminating village drinking supplies (Postel, 1993). At the same time, in a number of regions in India, water tables have been falling at average rates of two to three metres per year due to the growing number of irrigation wells. The resulting depletion of groundwater aquifers has some analysts predicting that 25 percent of India's harvest may be placed at risk in the coming years (Brown, 2000; Gleick 2000).

The world's biggest natural underground reservoir—the Ogallala–High Plains Aquifer System in the United States—has also witnessed one of the biggest environmental impacts witnessed in modern times. Since the early 1960s, farmers have been pumping 20 to 40 times more water annually than the natural recharge system is able to replenish. The result has been wealth for a favoured few in the states of Texas, Colorado, New Mexico, Kansas and Oklahoma, and insecurity for future generations (de Moor and Calamai, 1997). In northern China between 1958 and 1998, groundwater levels in the Hai River Basin fell by up to 50 metres in some shallow aquifers and by more than 95 metres in some deep aquifers (Ministry of Water Resource *et al.,* 2001).

Health effects: Irrigation waters have also been associated with contributing to harmful health effects. More than 30 diseases have been linked to irrigation (including Malaria, Japanese encephalitis, filariasis, etc.) (World Bank *et.al.*, 1998). Although it is impossible to quantify the additional toll of diseases which are related specifically to irrigation systems, it is fair to say that in agricultural areas these systems are important contributing factors in the overall burden of water-related diseases.

4.9.2 Costing environmental externalities

The cost of environmental externalities represents the costs of damage or the loss of welfare that irrigation water services and their use impose on the environment and ecosystems and those who use the environment. While some of these costs might be directly water related, others may be indirectly related to water or even non-water related (such as effects on soil or air). This loss in welfare may consider lost production or consumption opportunities as well as other, non-use values, which may be difficult to quantify but nonetheless correspond to real costs to society.

Despite the substantial environmental effects associated with the provision and use of irrigation water, very limited systematic research effort has gone into empirically quantifying their economic impacts. Such externalities are difficult to value, even if distinctly observable and attributable. Complexities include the difficulty of estimating the proportion of pollution contributed by different polluters and the problem of quantifying the cost of damage attributable to different players. External effects in general cannot be valued directly from market data because there are no prices for the resources associated with these external effects (MacDonald *et al.*, n.d.).

The only way to value these effects is indirectly—for example, through impact pathway analysis, the analysis of property prices or hedonic methods, and contingent valuation. However, the values derived from these methods are location specific and cannot be generalized (Markandya, n.d.). While all the enumerated methods have advantages, uncertainties and limitations in valuing external effects, they have limited applicability in the quantification of external effects related to the provision and use of irrigation water.

Another way to account for the costs of environmental effects is to assess the costs of prevention or mitigation. The costs of measures needed to prevent and mitigate damage to the environment and to maintain defined indicators of environmental health can be approximated to indicate what society should be willing to pay to avoid the environmental damage. However, care has to be taken to avoid double counting if some of the costs of prevention and avoidance have already been included in the financial cost.

Information on the environmental and resource costs caused by irrigation water supply and use is not systematically collected in any country. Because of the difficulties associated with the availability of appropriate data coupled with the methodological problems of valuing environmental costs, quantitative measurements have so far been limited. Such attempts are growing, but doubts persist about the validity of methods being used. For example, one of the methods used to internalize externalities is to impose a salinity levy on users, depending on their water-use patterns. This is used in the Australian state of Victoria, and the surcharge is determined by the cost of restoring the saline water to its original condition (and is generally greater than the abstraction cost that users have to pay). Where return flows from towns impose costs on downstream users, one approach is to levy a charge on urban consumers for restoring the wastewater to an acceptable condition (used in the German Ruhr and French systems) (Briscoe, 1995). Table 4.3 illustrates some additional examples of attempts at these evaluations.

Table 4.3 Examples of valuations of non-financial costs associated with irrigation

Case	Source	Valuation	Method
Recreation values attached to lake water levels vs. agricultural use (Nevada, U.S.)	Eiswerth *et al.*, 2000	Agricultural value: $0.1–0.035 per cubic metre Recreation: $0.14–0.525 per cubic metre	Revealed preference and contingent behaviour surveys
Social pollution costs measured by water treatment costs (Texas, U.S.)	Dearmont *et al.*, 1998	Due to sedimentation: $0.02 per cubic metre Due to groundwater pollution: $0.025 per cubic metre	Econometric analysis using urban supplier cost functions
Groundwater over-exploitation, measured by costs of correcting strategies (Spain)	MIMAM, 2000	$0.22–0.50 per cubic metre	Cost of water transfers to replace water taken from over-drawn aquifers (cost effectiveness analysis)
Environmental compensation tax for inter-basin transfers (Spain)	MIMAM, 2000	$0.027 per cubic metre	Environmental surtax imposed on water users to compensate regions (method not documented)
Salinity problems in the Murray River (Australia)	Mues and Kemp, 2001	$223 million	Net present value of the reduction in agricultural returns from high water tables.

Source: OECD, 2002.

Notwithstanding the methodological and data problems related to identifying, quantifying and attributing the environmental impacts of irrigation, there are some environment-related costs that can be quantified and attributed with a fair degree of approximation. In the case of saline and waterlogged soils, for example, irrigation water is the main reason for this externality. Irrespective of whether the fault lies with the irrigation water-supplying agency or with inefficient on-farm use of water, it is the farmer, and not the government, who has to bear the consequences and the cost of mitigation measures. However, in almost every country, and more so in poor countries and to poor farmers, the government often makes some contribution towards this private cost in the form of a subsidy to promote the supply of soil amendments such as gypsum or other inputs to deal with saline soils. The government thus pays a part of the cost of mitigation. Similarly, the lost production on account of land going out of cultivation due to non-adoption of mitigation measures is a cost both to the beneficiary of irrigation water as well as to society in the long run.

Similarly, to overcome the problem of waterlogging, while the on-farm cost of mitigation through the provision of drainage facilities has to be borne privately by the farmer, the system-level costs of mitigating waterlogging have to be incurred collectively in the form of the provision of drainage facilities, if these were not part of the original irrigation infrastructure. To deal with the problem of declining groundwater tables governments have often had to invest in artificial recharge structures, and the annualized cost of such capital investment is a cost to the government. The rise in the water table as a result of these investments is a net benefit to the farmer in so far as it reduces the cost of pumping.

Where satisfactory monetary valuation of environmental externalities is not possible because of a data deficit, it often suffices to identify and describe the effects in qualitative terms or in some other form of quantitative measure such as the amount of land affected or abandoned. This information is, however, not very useful for incorporating into the cost of environmental externalities associated with irrigation. However, this is not to undermine the urgent need to collect data on these aspects (though undertaking new studies to collect such data is complex, time consuming and expensive). Until the time such detailed data becomes available, it would be useful if some of the environmental costs of water services could be estimated by drawing on the existing data, bearing in mind the need to exercise caution to clearly set out all the assumptions used in the analysis, the limitations and the uncertainties associated with such estimation.

4.10 Gross cost to government

Based on the discussion in the previous sections, the gross cost to the government of supplying irrigation water can be described as the sum of:

- Annual capital cost (interest and depreciation charges) of irrigation infrastructure (Sections 4.3, 4.3.1 and 4.3.2);
- O&M costs (Section 4.4);
- Cost of providing water through groundwater (Section 4.5);
- Opportunity cost of irrigation water (Section 4.6);
- Opportunity cost of electricity used for irrigation pumping (Section 4.7);
- Resource cost of groundwater (Section 4.8); and
- Cost of environmental externalities (insofar as they can be quantified and attributable to government expenditure) (Section 4.9).

5 Revenues realized by government from irrigation water

Having discussed the issues relating to the determination of cost of providing irrigation water, the paper now focuses on the issues relating to revenue realization by the government. In the literature on cost recovery for irrigation services, the money realized from the farmers, the primary beneficiaries of irrigation water, in the form of irrigation charges is treated as revenue realized by the government on account of making irrigation water available. However, is this the only source of revenue for the government from the sale of irrigation water? Are farmers the sole beneficiaries of irrigation water and therefore the sole entities responsible for paying for irrigation water? The experience suggests that while farmers may be the primary beneficiaries of irrigation water, they cannot be regarded as the sole beneficiaries. Who are the other beneficiaries who gain directly or indirectly from the irrigation water made available to farmers? Is the government getting some of its irrigation-related revenues, knowingly or unknowingly, directly or indirectly, from some of these beneficiaries? Apart from the revenues realized from these segments of society impacted directly and indirectly by the availability of irrigation water, what are the other sources of revenue for the government from investments made in the irrigation sector?

We discuss this issue in two parts. The first part relates to identification of direct and indirect beneficiaries who gain from the availability of irrigation water. The paper then discusses the various sources of revenue for the government related to supply of irrigation water.

5.1 Identifying the beneficiaries of irrigation water

Construction and maintenance of irrigation infrastructure involves huge costs and therefore an important concern in making these public investments has always been how the costs of these investments can be recovered and who should pay for these costs (Sampath, 1983; Tradieu, 2004). In principle, any cost incurred in providing a service should be recovered from all those who benefit from the provision of these services (Barakat, n.d.). So, the first important question is: who are the beneficiaries of irrigation water?

While the primary concern for public investment in irrigation infrastructure is to help farmers adopt technological innovations and increase agricultural production, or to help minimize the impact of erratic weather patterns on agricultural production, this in no way can be regarded as the sole purpose for governments to invest in irrigation. In the literature on cost recovery, the difference between the "cost" of making irrigation water available and the irrigation charges recovered from the farmers in the form of water tariffs is referred to as a subsidy. The rationale behind recovering the cost of irrigation water (in whatever way the cost is defined) from the farmers, is that these investments have been made for the benefit of the farmers and the cost of providing irrigation water should therefore be borne by them and recovered from them.

It has however long been recognized that while farmers may be the primary beneficiaries of the investments in irrigation, they are rarely the sole beneficiaries. From even the most casual comparison of the economic activity in a region before and after the availability of irrigation, it would be obvious that the benefits of growth as a result of the availability of irrigation water are reaped not only by multiple segments of the rural population—both farm and non-farm—but often by residents of urban areas as well (Marts, 1956). Some derive these benefits directly, while others derive them indirectly through the benefits of increased agricultural production transmitted to other parts of the society. In addition to the economic benefits accruing to various segments of the rural and urban population, investments in irrigation provide a number of social benefits, such as enhanced food security, lower food prices and increased income-generating opportunities.

The fact that some benefits of irrigation are unintended and that some of these benefits accrue indirectly to non-agricultural sectors—does not make them any less real, valuable or important. The argument that it is not easy to identify other beneficiaries or to quantify indirect benefits, or the amounts these indirectly impacted beneficiaries are already paying to the government, does not mean that revenue realized from the direct beneficiaries alone can be treated as the sole revenue from sale of irrigation water. The difference between the cost of irrigation water and the money recovered from farmers in the form of water tariffs should not automatically be interpreted as a subsidy to the farmers. It is therefore desirable that at least some of these indirect benefits and beneficiaries be identified and properly accounted for, along with direct beneficiaries and the revenue realized from them on account of increased production attributable to the availability of irrigation water.

The number of indirect beneficiaries and the amount of indirect benefits in certain situations could be at least as large, if not more, as the number of direct beneficiaries and the amount of direct benefits (Garido, 2005). In the Canadian provinces of Alberta and Saskatchewan, for example, it has been estimated that 15 to 20 percent of the total benefits of irrigation go directly to the farmer, with the remainder to society (Hill, 1985). These benefits are from economic activity and employment beyond the farm—benefits derived from irrigation-related activity. Farm benefits often form a small part of the total benefit and projects become feasible only when all the beneficiaries contribute to the cost. When methods are found to access the wealth created by indirect benefits, projects would become more viable (Tollefson and Hill, 1994). That this part of the cost should be borne by other project beneficiaries and other indirect users has been emphasized by the Organisation for Economic Co-operation and Development (OECD, 2002) and the International Commission for Irrigation and Drainage (ICID) (Tardieu, 2004). While appreciating the need to recover costs from all beneficiaries, it is argued that since "it is not easy to identify the 'end beneficiaries' other than irrigating farmers, the community as a whole, i.e. the taxpayers could be charged for it" (Tardieu, 2004).

The direct benefits and direct beneficiaries have received much systematic study in the literature, and can be estimated within a reasonable margin of error. The procedures for identifying indirect beneficiaries and estimating indirect benefits and how the total benefits of a project have been shared by different segments of the society have been deficient. As such, it constitutes one of the most difficult problems in the economics of resource development. This is one of the many key issues which remain to be explored and require further methodological development.

5.1.1 Water resources development, direct and indirect benefits and beneficiaries, and sharing of economic benefits

As discussed above, investments in large water projects generate a vast array of economic impacts. These intended and unintended impacts include both direct effects and indirect, or multiplier, effects.[10] In general, *ex-post* and *ex-ante* evaluation of water projects often place a value only on the direct impacts—and indirect or multiplier impacts of such projects are generally not taken in to account. Ignoring these indirect impacts can result in underestimating the total impacts of a project.

The empirical evidence on the magnitude of indirect impacts of water projects and how the direct and indirect benefits of these projects are shared by different beneficiaries is, however, scarce. Limited empirical evidence available from Brazil (Cavalcanti and da Costa, 1988); India (Hazell and Ramasamy, 1991); Malaysia (Bell, Hazell and Slade, 1982); and the United States (Ortalano and Cushing, 2002) show large indirect benefits of such projects. Hazell and Haggblade (1990) estimated that in India a 100 rupee increase in agricultural incomes

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[10] Multiplier effects include both indirect economic impacts, arising as a result of backward and forward linkages, as well as the consumption-induced impacts of higher incomes.

generates an average of 64 rupees of rural non-farm income—39 rupees in rural areas and 25 rupees in rural towns. In a recent study, Bhattarai *et al.* (2004) reported an irrigation impact multiplier value for India ranging from 3 to 4.5.

A recent multi-country World Bank study on multiplier effects and the income distribution impacts of dams, using multi-sector economy-wide models, conclusively demonstrates that inter-sectoral and consumption effects of the large water-storage structures produce large economic gains and that these gains are shared by different segments of society, including rural poor households who have no land as well as urban households (Bhatia *et al.,* 2008). The multiplier value—denoting the summary measure that reflects the total effects, direct and indirect, of a project in relation to its direct effect—in Brazil (Sobradinho Dam); India (Bhakra Dam System); and Egypt (Aswan High Dam)—ranges between 1.4 to 2.0, implying that, for every dollar of added value generated directly by the project, another 40 cents to one dollar were generated in the form of indirect or downstream effects or benefits.

The Indian study of the Bhakra Dam also quantified the gains accruing to different sectors of the economy (see Table 5.1) resulting from the availability of irrigation water and hydropower, and how these gains have been shared by different categories of households (Bhatia and Malik, 2008). The method used was a combined analytical framework of optimizing models and a Social Accounting Matrix (SAM) fixed-price multiplier model. The results show that indirect impacts form a significant proportion of the total benefits emanating from the project. The estimated multiplier value of 1.90 implies that for every rupee of direct benefit derived from the project, another Rs 0.90 is produced in the form of indirect or downstream benefits. The results show that the average income of households rises by 29 percent. The benefits are shared by all categories of households, including urban households, albeit to a varying extent.

The most significant finding from the analysis shows that percentage income gains of agricultural labour households are much higher than the agricultural land-owning households (see Table 5.2 and Figure 5.1). While the income of landed households increased by about 42 percent, those of agricultural labour increased by 65 percent. The project benefited urban households also whose average income also increased by about 17 percent. Of the total increase in incomes, about 39 percent accrued to landed households, 17 percent to agricultural labour, five percent to non-agricultural rural households, 15 percent to other rural households, and the remaining 24 percent to urban households. These income gains raised the real income of such households still further when seen in conjunction with lower food-grain prices due to increased production as a result of the project, and availability of these food-grains through the "fair price shops"[11] throughout the country.

Further, the increased economic activity generated by the dam encouraged several thousands of workers to migrate to Punjab to look for employment opportunities. The remittances these workers sent home—estimated to be of the order of rupees 3,548 million ($75 million) in 1995–96—helped their families emerge from poverty and improve living conditions in places situated far from the dam project. Some of these impacts on the poor in other regions have not, however, been captured by the multiplier analysis. Incorporation of such multiplier impacts would raise the value of the project benefit multiplier still further.

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[11] Fair price shops, or ration shops as they are sometimes called, generally supply food-grains and other essential items to economically weak sections of society at prices lower than those prevailing on the open market.

Table 5.1 Estimated gross value of output and value added in simulation exercises using the SAM model for the Punjab: 1979–80 (millions of Indian Rupees)

	Gross value of output			Value added		
Sectoral Aggregation	**Without project**	**With project**	**Percent change**	**Without project**	**With project**	**Percent change**
Agriculture	15,137	22,072	46	9,870	14,398	46
Animal husbandry	5,583	7,976	43	3,919	5598	43
Agro-processing	3,734	5,566	49	473	727	54
Manufacturing	17,790	21,884	23	3,866	4,767	23
Electricity, gas and water	824	1,647	100	473	946	100
Construction and services	27,501	30,148	10	14,277	15,943	12
Total	70,568	89,294	26.5	32,878	42,379	29

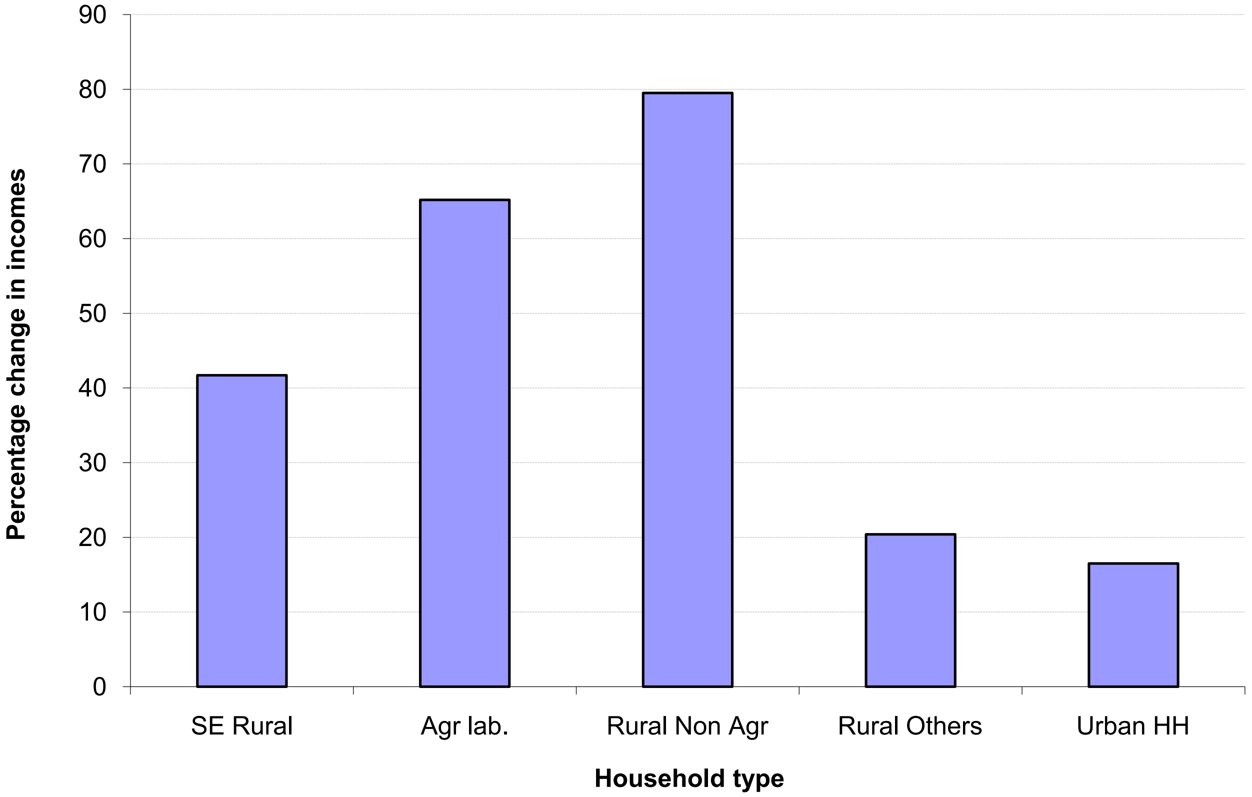
Source: Bhatia and Malik, 2008.

Table 5.2 Differences in incomes of agricultural labor and other rural households with and without the Bhakra Dam (millions of Indian Rupees)

Category of households	With project	Without project	Difference	Percent difference
Self-employed rural households	12,505	8,825	3,680	42
Agriculture labour	4,005	2,425	1,580	65
Rural, non-agriculture	1,125	627	498	80
Rural, others	8,413	6,988	1,425	20
Urban households	16,331	14,014	2,317	17
Total	42,379	32,878	9,501	29

Source: Bhatia and Malik, 2008.

Figure 5.1 Percentage increase in incomes of different categories of households with and without the Bhakra Dam



Source: Bhatia and Malik, 2008.

5.2 Sources of revenue to the government on account of irrigation water

Having identified the directly and indirectly impacted beneficiaries of irrigation projects, the paper now discusses the various sources of revenue for the government.

5.2.1 Directly and indirectly impacted beneficiaries

Given that the benefits of water projects accrue directly and indirectly to a wide range of beneficiaries, the basis of cost recoveries or revenue realization from these beneficiaries may also be direct or indirect.

In the literature on cost recovery of irrigation, the money recovered from the farmers, the primary beneficiaries of irrigation water, in the form of irrigation charges is treated as revenue realized by the government on account of making irrigation water available. The amount of irrigation charges that are recovered depends upon the price of water, the tariff regime and the efficiency of the water-supplying agency in collecting fees from the users. There are essentially three alternative tariff regimes in the irrigation sector: volumetric pricing methods, non-volumetric pricing methods, and market-based methods. Area-based tariffs, one of the forms of non-volumetric methods of charging, are the most commonly employed tariff regime in developing countries.

Apart from revenue realized in the form of water tariffs, the government occasionally also collects from users of irrigation water a fee in the form of a betterment levy (the incremental portion of land taxes attributable to irrigation investments). The government also sometimes imposes export taxes on crops that are cultivated mainly in irrigated areas. Sometimes governments also impose increased crop delivery quotas at controlled prices. These recoveries from farmers along with taxes collected from exporters also generate revenue for the government.

Indirect cost recovery refers to increases in government revenue attributable to an irrigation project, whose incidence is not borne by farmers in the irrigated area (Barakat, n.d.). Some of these revenues could be in the form of taxes collected from industries on increased turnover realized as a result of higher production attributable either directly to availability of irrigation water or arising as a result of consumption-induced income effects linked to the direct and indirect beneficiaries of irrigation water. In fact some of these beneficiaries have already been paying these charges in the form of direct and indirect taxes, however due to a lack of clarity on the nature of these beneficiaries and the accounting systems followed by the governments, these charges are typically not viewed and accounted for as payment towards the use of irrigation water. Simply because this is not an easy task using the prevalent accounting systems of the governments does not mean that these increased taxes should be treated as general revenue and not debited against the cost of providing irrigation water.

Some policies, such as an export tax on a cash crop like rice or cotton, may contribute both to direct and indirect cost recovery, affecting both producers and processors of the product. Revenue-realization instruments may also be classified as automatic, to the extent that a project may increase government revenue via existing tax instruments, or discretionary, when it pertains to instruments that are explicitly instituted to increase cost recovery.

As mentioned earlier, apart from benefiting, directly and indirectly, various parts of rural and urban society, availability of irrigation is also associated with a number of other social impacts. Enough empirical evidence is available to demonstrate the linkages between some of these variables and irrigation, notably the impact on poverty reduction, employment generation, lowering of food prices and food security. Some of the available evidence suggests that returns to education are much higher in irrigated districts as compared to non-irrigated districts (Pritchett, 2001). While financial quantification of these impacts is beset with methodological problems, the financial implications of these impacts are likely to be even greater than the direct and indirect economic gains demonstrated above.

5.2.2 Fish production

Irrigation systems, which consist of dams, reservoirs, main irrigation canals and their distributaries, water bodies formed by seepage, drainage canals and often drainage water storage, offer a diversity of water bodies for fish production.[12] Among these water bodies, usually only dams and reservoirs are used for fish production. Canal systems have been given low attention in terms of realizing their potential for fish production. Active canals are rarely managed for capture fisheries and there is no cage or pen culture evident. However, abandoned irrigation canals are to some degree utilized for fish production. Flood control compartments are often stocked naturally with wild juvenile fish, including major carps and other food fish, during floods. Large areas of wetlands resulting from irrigation practices also have considerable potential for fisheries development but are rarely utilized. There is also the tendency to build fish farms on marginally productive agricultural land or areas. As the dependence on the

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[12] Fish production in irrigation works, however, sometimes comes at the cost of opportunities available for fish production in natural water systems, systems which often are destroyed by the irrigation works.

canal water in fish farming systems is very high, one can consider these ponds to be an integral part of the irrigation system. The possibilities and scope for the utilization of irrigation systems for fish production, however, vary from project to project, depending upon the prevailing conditions with respect to availability, demand and management of water (FAO, 2001). There are a number of examples from several countries—India, Pakistan, Turkey, Uzbekistan, etc.—where irrigation systems are being used for fish production.

There is no organized effective data collection system which could assist in determining factors contributing to sustainable use of irrigation systems for fisheries or even the quantity of fish caught in these water bodies. Traditional inland fisheries are managed by an auction system and there is limited licensing of natural water bodies. Also, the fishing rights for each compartment are annually auctioned by the respective agency owning and maintaining the system. Even if reliable estimates of fish production arising from various components of an irrigation system are not available, data on the prices at which various compartments are auctioned are available, and such data can provide an estimate for revenue derived from these fisheries.

5.2.3 Hydro-electric power generation

Some irrigation projects, even those not forming part of a multi-purpose project, have provided opportunities for generating hydro-electric power, a non-consumptive use of water. In addition, in locations where the gradient and quantity of water available is conducive, canal drops can often be used for hydro-electric plants. The economics of hydro-electric power generation depend upon the prevailing water and power availability policies, and the priorities given to the use of water between the two purposes.

In energy-scarce economies, hydro-electric power can provide a valuable adjunct to an irrigation project and can provide power during peak demand that is sometimes priced higher than off-peak power. Thus the value of hydropower is likely to be higher in situations of high water availability, where the conflicts between its use for irrigation and power generation are low, and acute power scarcity is prevalent. Because the output of a hydro-electric power plant can be varied quickly in response to changing demand, it often commands a premium price.[13]

5.2.4 Electricity supplied for groundwater pumping

There are essentially four alternative regimes of electricity pricing for irrigation pumping widely practised in most of the developing and even developed countries. The first, free provision of electricity, needs no explanation. The second is a system of flat rates (FRs) under which a pump owner is charged at a flat monthly rate per horsepower of the pump or a graduated flat rate according to the horsepower of the pump in either case, regardless of actual power use. In this method, the marginal cost of pumping more water is zero and the farmer has no incentive to conserve water, and may even pump water surplus to his own needs in order to sell it to other farmers.

The third type of pricing system is to charge the farmer per kilowatt-hour of power consumed on the basis of metered consumption of electricity. This may be a constant rate irrespective of the amount of electricity consumed or may vary according to the amount utilized (a block-rate tariff). The fourth regime, a two-part tariff system, is a mixture of the metered and fixed-rate tariff systems wherein users are charged a fixed amount based on the horsepower of the pump and a variable amount based on actual metered consumption. While farmers in

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[13] If a hydropower plant is owned by a private entity, the revenue to the government based on the use of irrigation water for the generation of electricity is derived on the basis of a commercial agreement entered into between the irrigation department and the generator of the hydropower, which could be a lump sum or determined on a profit-sharing basis. In the case of the hydropower plant being owned and operated by the irrigation department of the government, which also owns and operates the irrigation infrastructure, the revenue from hydropower would depend upon the commercial net value of the power generated.

some countries still receive electricity at no charge for running irrigation pumps, the flat-rate tariff system is the most common.

Whatever the charging system, or the size of the tariff, the revenue realized by the government or the power utility from the farmers on account of supplying electricity for the running of tube wells is to be credited as revenue realized for providing irrigation.

5.2.5 Tourism and recreation

Irrigation reservoirs, dams and canals offer opportunities for water-related sports and offer other recreational options. This helps in promoting tourism. The government derives large revenues from these structures which must be duly accounted for in government accounts as revenues from irrigation.

5.2.6 Revenues from the imposition of pollution taxes

Economists have generally advocated the use of pollution taxes as a means to address environmental externalities. Following the "polluter pays" principle, the externality problem in general is sought to be addressed by imposing environmental levies and taxes on the polluter. In line with this principle, the polluter should pay, or the governments should recover, in addition to the cost per unit of water, an additional charge per unit of water equal to the external damage cost imposed on others (MacDonald *et al.*, n.d.)

In the case of irrigation water, even if it were possible to somehow quantify the damages, identifying the polluters of irrigation water, and clearly demarcating the nature of damages and attributing the share of damages to irrigation water *per se* and to different polluters, is not straightforward. As discussed earlier, while some of the irrigation-related externalities are caused because of inefficient use of irrigation water, some may be caused by the providers (irrigation agencies) of irrigation water as a result of faulty infrastructure design or the poor quality construction of irrigation works, or poor maintenance of the system. Further, some of these externalities can be increased by household sewage or industrial effluents mixing with irrigation water—that is, by individuals or firms not engaged in agriculture. In addition, the externalities often stretch over large areas, which make it difficult and expensive to monitor their origin, to quantify the magnitude of different damages caused by different actors, and to allocate the cost of damages among different polluters and thereby make someone accountable, in particular, for causing these externalities. This is a subject which lacks clear answers and agreements and calls for further research.

In view of these complexities it is not known if any country imposes pollution taxes and recovers them from the beneficiaries of irrigation water; however, if it were feasible to do so, this would add to the revenues of the government and need to be accounted for.

5.2.7 Non-quantifiable returns

Apart from the quantifiable revenues to the irrigation providing agency, there are a number of other benefits to the government in general, which are difficult to quantify in monetary terms. Enough evidence is available to substantiate that the availability of irrigation water is associated with rural development, a reduction in poverty, improved food-grain availability and food security, lower food-grain prices, improved hygiene and sanitary conditions, improved returns to education, etc.

5.2.8 Total revenues to the government from irrigation water

The total revenue to the government from investments made in the provision of irrigation water thus comprises:

- Revenue realized on account of the sale of water from the direct and indirect beneficiaries of irrigation water (Section 5.2.1);
- Revenue realized from the sale of hydropower generated from the running of river based hydropower plants (Section 5.2.3);
- Revenue realized from the sale of fishing rights (Section 5.2.2);
- Revenue realized on account of the sale of electricity to the agricultural sector for irrigation pumping (Section 5.2.4);
- Additional revenue realized on account of increased tourism and tourism-related activities (Section 5.2.5); and
- Revenues from the imposition of pollution taxes insofar as they relate to provision and use of irrigation water (Section 5.2.6).

5.3 Subsidies on irrigation: net cost to the government

The subsidy or net cost to the government in making available irrigation water is the difference between the gross cost to the government (Section 4.10) and revenue realized from the different beneficiaries of irrigation water (Section 5.2.8).

6 Net benefit to the recipient approach

The second approach for measuring subsidies is based on the actual value of water to the irrigator rather than the expenditure incurred by the government. Thus, the irrigation subsidy, when following this approach, is the difference between the water's net economic benefit to the irrigator per unit of water and the price paid per unit of water. As already discussed, apart from the farmers, who are the direct beneficiaries of irrigation water, there are other segments of the society who receive benefits indirectly from irrigation water through multiplier effects as well as through informal uses of irrigation water. In addition, there are additional benefits in the form of return flows. The availability of irrigation water also affects society in general in both positive and negative ways. The paper first defines the gross benefits occurring to the various beneficiaries of irrigation water and then defines the costs paid by them. Having made this calculation the net benefits to the beneficiaries is then estimated.

6.1 Identifying and quantifying the benefits

6.1.1 Direct beneficiaries: the farmer

The primary beneficiary of irrigation water is the farmer. The value of irrigation water to the farmer can be approximated by the marginal value product (MVP) of water, which is based on the incremental yield, or marginal physical product (MPP) of water (Tiwari, 1998; Tiwari and Dinar, 2001). If perfect markets for irrigation water existed, this value could be equated with the market price of water. However, since markets for irrigation water either typically do not exist or are highly imperfect, it is not easy to determine what this value is. Moreover, the market value of water will vary by location and crop grown. A patchwork of methods has therefore been used in the literature to estimate the value of water (Gibbons, 1986; Briscoe, 1997).

One of the possible ways to evaluate this value is to ascertain the maximum amount the farmer would be willing to pay for using the resource. The farmer's willingness to pay (WTP) for water can be estimated using contingent valuation methods. Estimates of WTP are however also beset with problems. The WTP for irrigation water is determined jointly by product price and the marginal productivity of irrigation. The "marginal product" of water and therefore the WTP is likely to differ between locations, because geographical location, amongst other things, determines the choice of crops that can be cultivated. In addition, one would even expect differences in WTP over time for the same location since product prices may change. The implication is then that in order to calculate the WTP for irrigation, not only region-specific estimates need to be generated, but these would also need to be updated regularly.

In general therefore the MPP is calculated based on a generic crop-water production function or farm-level budget data. Thus, for a farmer, the MVP can be approximated by the increase in income from farming before and after the availability of irrigation water. If both non-irrigated and irrigated crops are produced within a homogenous growing region, the MVP can be obtained by comparing the average commercial value yield from irrigated lands in the district, with the average yield on non-irrigated lands (Gardner, 1983).

When water rights are traded as in the western states of the United States, the market value of the land incorporates the MVP of water (Cummings and Nercissiantz, 1992). Land value differentials thus provide yet another method of measuring the rent implicit in access to irrigation water and thus calculating the subsidy (Cummings and Nercissiantz, 1992).

Additional insights into the benefits provided from the availability of irrigation water can be gained by using a mathematical programming model of farming operations. In fact, mathematical programming is traditionally the tool of choice to simulate irrigation water values (Gibbons, 1986). Such a model features an objective function—

agricultural incomes, for example, defined as the difference between commodity sales revenue less expenditure on commercial inputs—as well as a series of constraints (Hazell and Norton, 1986; Malik, 1991). One such constraint may relate to land availability, labour availability or water availability. Any run of a mathematical programming model indicates the shadow price of each limiting resource. Thus, in the case of water, the additional net earnings associated with increasing water supplies by a single cubic metre can be estimated.

Mathematical programming models can also be employed to ascertain more substantial information relating to the removal of any water constraints. Thus the opening up of an irrigation system can relax the water availability constraint and could easily lead to changes in the mix of inputs and outputs which then alter the resource shadow price (Malik, 1991). A mathematical programming model is run first with the original level of water supplies, thereby obtaining an estimate of income without irrigation. Next, net earnings with the irrigation project are estimated by running the model with the higher level of water supply (Southgate, 2000).

In those economies where farming systems include livestock as an important component and provide a significant portion of farming income, irrigation water availability also helps meet the water requirements of livestock management. Returns to irrigation water for the farmer beneficiary thus must include additional returns from livestock rearing and from any on-farm fishing ponds fed by irrigation water.

6.1.2 Benefits to indirect beneficiaries

Apart from farmers, who are the direct beneficiaries of irrigation water, there are other segments of society who also benefit through indirect impacts of irrigation water. Therefore, in addition to farmers, the gains occurring to these parts of society are also attributable to the availability of irrigation in the sense that these gains would not have occurred had the farmers not been supplied irrigation water. Thus, from the perspective of those segments of society that benefit indirectly from the supply of irrigation water to farmers, their gains can be approximated by the net increase in their incomes realized as a result of the availability of irrigation water to farmers.

6.1.3 Some other benefits

Apart from these indirect beneficiaries, many multi-purpose irrigation schemes also provide water for households (for example, cooking, drinking and bathing), and industrial use. These benefits, though difficult to quantify, must be kept in view.

6.1.4 Benefits of return flows

Surface water and groundwater form parts of the same hydrological system. While a large portion of the water lost in the transmission and distribution of surface water is due to evaporation, some ends up recharging the groundwater lying below the surface. Also, a part of the water applied to crops directly leaches down and recharges the groundwater table. The effect of a return flow of irrigation water in water-scarce areas is reflected in terms of a rise in groundwater tables or in terms of slowing the rate at which groundwater tables decline. In situations where the groundwater tables are high, the return flows may act as a negative externality because they exacerbate problems of waterlogging and soil salinity. These negative benefits (costs) are discussed in more detail below. In situations where the groundwater tables are declining, the return flows are beneficial in the sense they help raise the groundwater table. The benefits to the user or the recipient linked to the rise in the water table are reflected in terms of a decline in the cost of groundwater extraction.

6.1.5 Benefits to the non-beneficiaries

Apart from the above-recognized benefits accruing directly and indirectly to direct and indirect beneficiaries of irrigation water, non-recipients also often gain from the availability of irrigation water though the nature and extent of these benefits may vary from project to project. Some of the benefits that direct and indirect beneficiaries share with non-beneficiaries include rural development, improved general infrastructure, food security, poverty reduction, improved hygiene, improved education, increased tourism and recreational facilities. Availability of water is also associated with cultural, aesthetic, merit, bequest and pure existence values.[14] Some of these benefits are often neglected since these cannot always be quantified in monetary terms, but are essential to the integrated decision-making process (Savenije and van der Zaag, 2001).

6.1.6 Total benefits to the users

The total benefits of irrigation water to users, to the extent these benefits can be quantified, thus comprise the following:

- Benefits to direct beneficiaries (Section 6.1.1);
- Increased incomes of those indirectly benefited (Section 6.1.2); and
- Benefits of return flows (Section 6.1.4).

6.2 Costs to the beneficiaries

6.2.1 User charges for surface and groundwater

The cost to the farmer of using the irrigation water is the payments made as user charges to the water-supplying agency. In addition to the user charges payable for surface water, the farmer may have to incur the cost of groundwater extraction. The cost of groundwater extraction consists of the annualized capital cost of a tube well plus the cost of electricity for groundwater pumping. In those countries where the groundwater usage charges are payable, the farmer in addition would need to pay these.

6.2.2 Cost of mitigation of degraded soils and environmental externalities

As discussed earlier, use of irrigation water has often been associated with increased incidences of soil salinity and waterlogging. While some of this soil degradation could occur on-farm, some could occur off-farm. The cost of soil degradation can be evaluated in terms of loss in land productivity. In addition, the user also incurs the cost of mitigating saline and waterlogged soils on their land. As discussed earlier, part of the private costs of mitigation is sometimes shared by the government in the form of a subsidy for soil amendments. In case of waterlogged soils, the farmers often invest in drainage to ameliorate this condition.

The costs of environmental degradation, including water pollution caused by runoff from agricultural fields or effluents from industry or the discharge of sewage into irrigation canals, are generally not recovered from the farmers due to the methodological and data problems associated with their quantification and attributing these

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[14] This is essentially to imply that irrigation water apart from providing tangible and intangible benefits to those directly and indirectly benefited, it also provides some other positive impacts. It adds value to nature, such as scenic beauty, etc.

costs to different polluters. Some countries may impose an *ad hoc* pollution tax on the farmer to partly recover some of these mitigation costs.

6.2.3 Total costs to the users

The total cost to the users of groundwater is the sum of the following:

- User charges for surface and groundwater (Section 6.2.1); and
- The cost of mitigating of degraded soils and environmental externalities (Section 6.2.2).

6.3 Subsidies on irrigation water: net benefits to the recipients

Having defined the benefits from the perspective of irrigation water users, those who benefit directly or indirectly from irrigation water, as well as those non-beneficiaries who share some of the common benefits with the direct and indirect beneficiaries, and also having defined the costs which the beneficiaries incur on account of using irrigation water, the paper now moves onto estimate the subsidies. The net benefits to the users or an estimate of subsidy, from the perspective of the users, are estimated by deducting the total benefits (Section 6.1.6) from the total costs (Section 6.2.3).

7 Data requirements and sources

The suggested approaches to estimating irrigation subsidies, though not entirely new, are not currently practised for estimating and reporting estimates of irrigation subsidies. However, the European Union's, Water Framework Directive (WFD) which came into force in 2000, has asked its member countries to report the costs of water services following a somewhat similar approach. The WFD generally deals with water in its totality and therefore does not address in detail the issues pertaining to allocation of joint costs. The first-time data requirements for estimating irrigation subsidies following the approaches suggested in this paper are enormous and may require substantial financial and human resources to collate data from different sources and put them in a useable format. However, once the historical data sets have been obtained and put in the framework, their subsequent updating should be relatively straightforward.

Some data (such as on financial investments, O&M costs and revenue realized) should be generally available from governments. Local-level data, such as those involving Water User Associations, might be available only from local agencies. In the case of multi-purpose projects, for the purpose of joint-capital cost allocation, such aggregate data may not generally suffice and one may need to undertake detailed on-site evaluations of existing infrastructures. Some data may reside only in the original project documents, which may or may not be obtainable from the responsible water agency. For allocating O&M costs to different users of a multi-purpose project, one may have to get the necessary data from the project authorities and make its allocation into different components in consultation with them.

Currently available estimates of irrigation subsidies generally do not go into such details of cost allocation and often treat the cost of multi-purpose projects as attributable entirely to irrigation. Obtaining the requisite data for several decades from government agencies and project authorities in such detail is not an easy task since some of the data may be classified or, even if not classified, the government agencies may simply refuse to part with the data for political or trade-related considerations. Researchers attempting to estimate irrigation subsidies would need to work closely with government agencies in obtaining the appropriate data and other related information. This is normally possible only if the governments agree to the proposed methodology and show their commitment and interest in estimating irrigation subsidies.

Assuming that the required financial and other associated data relating to capital cost, O&M costs and revenues realized can somehow be obtained from government records, one would need to estimate the data on some of the other variables such as the opportunity cost of water. Given the heterogeneity in the demand–supply position of water in different locations within a country, special region-specific studies may thus need to be undertaken to derive estimates of opportunity cost of water for a representative sample of sites within a country. Further, most data is collected and reported at the national level. But environmental (and social) impacts are typically local.

Region-specific studies may also need to be undertaken to identify the beneficiaries of water that are other than farmers and to derive some estimates of the share of benefits derived by different beneficiaries from direct and indirect impacts of irrigation. Data on some aspects, such as impacts of resource degradation (soil and water) on crop productivity for example, may need to be drawn from research studies undertaken by universities and research institutions. Additional special surveys may have to be undertaken to fill in data gaps, and the remaining ones may have to be filled in on the basis of expert judgment. This approach is likely to be more cost effective.

The data on certain variables, such as revenue realized from farmers from the sale of irrigation water, or the benefits derived from the use of irrigation water, are likely to vary substantially depending upon total water availability, which could vary from year to year depending upon rainfall. It is suggested that if the specific year for which subsidies are being estimated is an abnormal year, data on some of these variables may need to be obtained for three years, in order to address such anomalies and ensure broad consistency in the financial data that are obtained.

There is considerable interest, particularly within the trade policy community, in generating estimates of subsidies at the country level. Because of the vast differences in sizes of countries—for example, between the United States and Portugal or Sri Lanka—such comparisons may involve aggregations across different geographic scales. Ideally, all estimates would be built up from data at no smaller than the river-basin level. However, the boundaries of basins do not always correspond with the boundaries of the administrative unit (such as a district or a state) at which data required for the present purpose may be available. Some researchers have suggested that for a country-level analysis, the entire irrigation infrastructure can be divided into two parts: (1) the system of dams, storage facilities and canals (main canals, branch canals and distributaries) that capture, store and distribute water to irrigated areas (the "primary and secondary" levels); and (2) the local system of field channels carrying water to farms (the "tertiary" level) (Hussain, 2004).

Given the complexities of this approach, it would seem appropriate that the geographical unit for estimation may be treated flexibly and decided on the basis of specific conditions prevailing in a given country and the system of data reporting and availability of data required.

Conceptually, both the methods of estimating irrigation subsidies discussed in this paper have both positive and negative attributes. The volume of data needed for estimating irrigation subsides by either of the two methods is equally large. Both the methods require substantive efforts in evolving methodologies for estimating the values of some of the parameters. Both require substantial efforts in estimating subsidies for the first time. The preference of one method over the other for estimating irrigation subsidies should generally be dictated by the availability of data and the ease with which estimates of various parameters can be derived. After methods for estimating various parameters in both the methods have been standardized, data gaps filled and first-time estimates of subsidies derived, updating the estimates of subsidies during later years would not be as difficult. In a few case studies, both the methods can be employed initially to empirically estimate subsidies on a somewhat smaller scale (such as at the level of a province or district) to more clearly understand the complexities involved and the amount of effort required to derive these estimates. There may be potential, depending on the size of the district, for extrapolating sub-national figures into national subsidy estimates.

In general, an initiative has to make publicly available the documentation and subsidy data and the methods currently being followed to estimate these subsidies by official agencies. This would help initiate better informed discussion on this issue and policy decisions regarding the sector, and, in the long run, would help improve the quality and comparability of the estimates of irrigation subsidies.

8 Conclusions and recommendations

The importance of irrigation water in increasing agricultural production and in raising the incomes of beneficiaries is well recognized. Most of the world's irrigation systems have been built and operated by government agencies. Almost everywhere, irrigation systems supply irrigation water at highly subsidized prices in the sense that water users are charged only a fraction of the cost of supplying water to them. The available estimates of irrigation subsidies are generally derived as the difference between the "cost" of supplying irrigation water and the "revenue" realized from the sale of irrigation water to what can be considered the "beneficiaries."

A perusal of the methods employed in arriving at some of the available estimates of irrigation subsidies suggests that an assortment of concepts and methods have been used to define costs and revenues and therefore to estimate irrigation subsidies. Since the available subsidy estimates differ both on conceptual and methodological considerations, and lack transparency in their use of the data, the estimates derived do not render themselves comparable across countries or studies. There is as yet no internationally agreed method for estimating irrigation subsidies. Nevertheless, it is not too soon to establish the necessary groundwork for measuring subsidies for irrigation so that better, and internationally comparable, estimates become available sooner rather than later. With the advent of the World Trade Organization, issues relating to subsidies have come into more prominence and efforts to define, measure and analyze subsidies in various sectors have gained momentum.

An attempt has therefore been made in this paper to promote discussion on the adoption of a methodology for estimating irrigation subsidies that can be applied to estimate and report them in a manner that is comparable across a range of developing and developed countries. A related objective is for the results of this research to lead to the improvement of other research efforts (notably policy modelling) and, ultimately, to improvements in both domestic policies and international trade rules. Since the estimation of irrigation subsidies is likely to differ depending upon the perspective of the analyst, the paper attempts to provide a methodological framework to estimate subsidies from two different perspectives: (a) from the perspective of the irrigation-water-supplying agency; and (b) from the recipients' point of view.

An important constraint in estimating irrigation subsidies following either approach is the non-availability or denial of access to detailed and disaggregated data on a large number of variables that are required for estimates to be made. Therefore the first-time data requirements for estimating irrigation subsidies following the approaches suggested here are enormous and may require substantial financial and human resources to collate data from different sources and put them in a useable format. However, once the historical data sets have been obtained and put in the framework, their subsequent updating should be relatively straightforward.

To validate empirically the methodologies suggested in this paper and to test their robustness in generating more comparable inter-country estimates of irrigation subsidies, it would be appropriate that at least two empirical case studies—one in a developing country and the other in a relatively developed country—be undertaken as part of testing the applicability of the methodology .

References

Abu-Zeid, M. "Water Pricing in Irrigated Agriculture," paper presented at the international conference Irrigation Water Policies: Micro and Macro Considerations, Agadir, Morocco, 2002

Abu-Zeid, M. "Water pricing in irrigated agriculture." Water Resources Development 17 no. 4 (2001): 527–38.

Barakat, E. "Cost Recovery for irrigated agriculture: Egyptian experience." Article 60 of the proceedings of the Conference in Agadir: Les Politiques d'irrigation considerations micro et macro economiques. Morocco, 15–17 June 2002.

Barakat, E. "Cost Recovery in Irrigated Agriculture: Egyptian Experience." Ministry of Water Resources, Egypt. n.d.

Bazza, M. and Ahmad, M. *A Comparative Assessment of Links between Irrigation Water Pricing and Irrigation Performance in the Near East*, Food and Agricultural Organization (FAO), Rome/Italy, 2002.

Bell, C., Hazell, P. and Slade, R. *The Project Evaluation in Regional Perspective—A Study of an Irrigation Project in Northern Malaysia*, 1982.

Bhatia, R. and Malik, R.P.S. "Indirect Economic Impacts of Bhakra Dam System." In Bhatia, Ramesh, Cestti, Tita, Scatatsta, Monica and Malik, R.P.S., eds., *Indirect Economic Impacts of Dams*, Academic Foundation, 2008.

Bhatia, R., Brisoce, J., Malik, R.P.S. and Mishra, S. "Water in the Economy of Tamil Nadu: More flexible water allocation policies offer a possible way out of water-induced economic stagnation, and will be good for the environment and the poor." *Water Policy* 8 no. 1 (February 2006).

Bhattarai, M., Sakthivadivel, R. and Hussain, I. *Irrigation Impacts on Income Inequality and Poverty Alleviation: Policy Issues and Options for Improved Management of Irrigation System*, Working Paper 39, International Water Management Institute, Colombo/Sri Lanka, 2002.

Bosworth, B., Cornish, G., Perry, C. and van Steenbergen, F. *Water Charging in Irrigated Agriculture*, Report OD 145, HR Wallingford, Wallingford, England, 2002.

Briscoe, J. "Implementing the new water resources policy consensus: Lessons from good and bad practices." In Lundqvist, J. and Jonch-Clausen, T., eds., *Putting Agenda 21 into Practice*, Linkoping University, Sweden, 1994.

Briscoe, J. "Water as an Economic Good: The Idea and What It Means in Practice." Paper presented at the World Congress of the International Commission on Irrigation and Drainage, Cairo, 1996.

Briscoe, J. "Managing water as an economic good: Rules for reformers." Keynote paper to International Commission for Irrigation and Drainage Conference on Water as an Economic Good, Oxford, 1997. Also in *Water Supply* 15 no. 4 (1997): 53–172.

Brown, L.R., Flavin, C., French, H., Postel, S., Starke, L., Halweil, B., Mattoon, A.T., McGinn, A.P., O'Meara, M., Renner, M., Abramovitz, J.N., Bright, C., Dunn, S. and Gardner, G. *State of the World 2000*, 2000. <http://www.worldwatch.org/pubs/sow/2000/>.

Cosgrove, W. and Rijberman, F. *World Water Vision: Making water everybody's business*. Earthscan Publishers, London, 2000.

Dearmont, D., McCarl B.and Tolman D. "Costs of Water Treatment due to Diminished Water Quality: A Case Study in Texas," *Water Resources Research,* 34(4), 849-853, 1998.

Diao, X. and Rao, T. "The Effects of Sequencing Trade and Water Market Reform on Interest Groups in Irrigated Agriculture: An Inter-Temporal Economy-Wide Analysis of the Moroccan Case," Bulletin Number 98-5, University of Minnesota, Economic Development Center, 1998.

Dinar, A. and Subramanian, A. "Water Pricing Experiences: An International Perspective." Technical Paper No. 386, The World Bank, Washington D.C., 1997.

Dinar, A., and Tsur, Y. "Efficiency and Equity Considerations in Pricing and Allocating Irrigation Water." Policy Research Working Paper, The World Bank, Washington D.C., 1995.

de Moor, A. *Subsidies and Sustainable Development: Key issues and Reform Strategies*. San Jose: Earth Council, 1997. <http://www.ecouncil.ac.cr/>.

de Moor, A. and Calamai, P. *Subsidizing Unsustainable Development: Undermining the Earth with public funds*. Earth Council, San Jose, 1997.

Eisworth M., Englin J., Fadali E., and Shaw W.D. "The value of water levels in water-based recreation: a pooled revealed preference/contingent behaviour model." Water Resources Research, 2000.

Easter, W.K. and Liu, Y. "Cost Recovery and Water Pricing for Irrigation and Drainage Projects." Agricultural and Rural Development Discussion Paper 26, The World Bank, Washington D.C., 2003.

FAO. "Report of the FAO Expert Consultation on the use of irrigation systems for sustainable fish production in Arid countries of Asia" FAO Fisheries Report No 679 (FIRI/R679), Rome: Food and Agricultural Organization.

Foster, C.D. and Beesley, M.E. "Estimating the Social Benefit of Constructing an Underground Railway in London." *Journal of the Royal Statistical Society*, Vol. 126, Part 1, 1963.

Garrido, A. "Using good economic principles to make irrigators become true partners of water and environment policies." Organization for Economic Co-operation and Development Workshop on Agriculture and Water: Sustainability, Markets and Policies, 2005.

Gibbons, D.C. *The Economic Value of Water*. Resources for the Future, Washington D.C., 1986.

Gleick, P. *The World's Water 2000–2001*. Island Press, Washington D.C., 2000.

Gulati, A. and Narayanan, S. *The Subsidy Syndrome in Indian Agriculture*. Oxford University Press, New Delhi, 2003.

Gulati, A., Svendsen, M. and Choudhary, N.R. "Capital Costs of Major and Medium Irrigation Schemes in India." in Svendsen, M. and Gulati, A., eds., *Strategic Changes in Indian Irrigation,* MacMillan India Limited, 1995.

Gleick, P., ed. *Water in Crisis: A Guide to the World's Fresh Water Resources*. Oxford: Oxford University Press, 1993.

Hazell, P.B.R. and Ramasamy, C. *The Green Revolution Reconsidered: The Impact of High-Yielding Rice Varieties in South India*, Baltimore, MD: The Johns Hopkins University Press, 1991.

Hellegers, P. "Treating Water in Irrigated Agriculture as an Economic Good." Paper presented at the international conference Irrigation Water Policies: Micro and Macro Considerations, Agadir, Morocco, 2002.

Hellegers, P.J.G.J. and Perry, C.J. *Water as an economic good in irrigated agriculture: Theory and practice.* Report 3.04.12., Agricultural Economics Research Institute, The Hague, 2004,

Hussain, I. "Have Low Irrigation Service Charges Disadvantaged the Poor?" International Water Management Institute, Colombo, Sri Lanka, 2004.

ICWE (International Conference on Water and the Environment). *The Dublin statement and report of the International Conference on Water and the Environment.* Development issues for the 21st century, Dublin, 26–31 January, 1992.

ISPAN (Irrigation Support Project for Asia and the Near East). *Irrigation water cost recovery in Egypt: Determination of irrigation water costs.* Arlington, VA, 1993.

Jin, L. and Young, W. "Water Use in Agriculture in China: Importance, Challenges, and Implications for Policy." *Water Policy*, 3, pp. 215-228, 2001

Johansson, R.C. *Pricing Irrigation Water: A Literature Survey*. The World Bank, Washington D.C., 2000.

Lin, Z.-C.. *Participatory Irrigation Management by Farmers – Local Incentives for Self-Financing Irrigation and Drainage Districts in China*, The Environmental and Social Development Unit, WBOB, The World Bank, 2002.

Li, X. and Li, H. "Institutional Options for Management Turnover: Guanzhong Irrigation System." Paper for the 6th International Seminar on Participatory Irrigation Management, Beijing, 2002.

Lohmar, B., Wang, J., Rozelle, S., Huang, J. and Dawe, D. "China's Agricultural Water Policy Reforms: Increasing Investment, Resolving Conflicts, and Revising Incentives." Agriculture Information Bulletin No. 782, Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture, Washington D.C., 2003.

MacDonald, D.H., Young, M.D. and Connor, J.D. *Pricing Water – a Tool for Natural Resource Management in the Onkaparinga Catchment.* Policy and Economic Research Unit, CSIRO LAND and WATER, n.d.

Malik, R.P.S. "Optimum Factor Combination in Agriculture: A Programming Model of an Agricultural District." Unpublished Ph.D. thesis, Delhi School of Economics, University of Delhi, Delhi, India, 1991.

Malik, R.P.S. and Faeth, P. "Rice-Wheat system in Punjab." In Faeth, P., ed., *Agricultural Policy and Sustainability: Case Studies from India, Chile, Philippines and US*, World Resources Institute, 1992.

Markandya, A. "The Costs of and Pricing of Water." The World Bank, n.d.

Marts, M.E. "Use of Indirect Benefit Analysis in Establishing Repayment Responsibility for Irrigation Projects." *Economic Geography* 32 no. 2 (April 1956): 132–38.

Martin, W.E., Ingram, H.M. and Griffin, A.H. *Saving Water in a Desert City*. Resources for the Future, Washington, D.C., 1984.

Massarutto, A. "The full cost recovery of irrigation: rationale, methodology, European experience." Paper presented for the International Conference on Irrigation Water Policies: Micro and Macro Considerations, Agadir, 15–17 June 2002.

MIMAM (Ministerio de Medio Ambiente),"Plan Hidrológico Nacional. Madrid: Ministerio de Medio Ambiente.," Madrid, 2000.

Ministry of Water Resource, World Bank, and AusAID. *Agenda for Water Sector: Strategy for North China*, No. 22040-CHA, Ministry of Water Resources, World Bank and AusAID, 2001.

Mues C. & Kemp A., 'Salinity management: Assessing priorities," paper presented at Outloook 2001, Managing Agricultural Resources, ABARE, Canberra, 2001.

Myers, N. and Kent, J. *Perverse Subsidies: How Tax Dollars Can Undercut the Environment and the Economy*. Island Press, Washington, D.C. (in cooperation with the International Institute for Sustainable Development), 2001.

Nyberg, A. and Rozelle, S. *Accelerating Development in Rural China*. World Bank Monograph Series, Rural Development Division, The World Bank, 1999.

OECD (Organisation for Economic Co-operation and Development). *Transition to Full-Cost Pricing of Irrigation Water for Agriculture in OECD Countries*. Environment Directorate and Directorate for Food, Agriculture and Fisheries, Paris, 2002.

OECD (Organization for Economic Co-operation and Development). *The Price of Water: Trends in OECD Countries*. Paris, 1997.

Ortolano, L., Cushing, K. and contributing authors. "Grand Coulee Dam and the Columbia Basin Project, USA." Case study report prepared as an input to the World Commission on Dams, Cape Town, 2000.

Perret, S. and Geyser, M. "The full financial costs of Irrigation services: A discussion on existing guidelines and implications for smallholder irrigation in South Africa." *Water SA* 33 no. 1 (January 2007).

Perry, C.J. "Charging for Irrigation Water: The Issues and Options, with a Case Study from Iran." IWMI Research Report 52, International Water Management Institute, Colombo, Sri Lanka, 2001.

Perry, C.J. "Alternative Approaches to Cost Sharing for Water Service to Agriculture in Egypt." Research Report 2. International Irrigation Management Institute, Sri Lanka, 1986.

Perry, C.J., Rock, M. and Seckler, D. "Water as an Economic Good: A Solution or a Problem?" Research Report 14, International Irrigation Management Institute, Sri Lanka, 1997.

Postel, S. *Dividing the Water: Food Security, Ecosystem Health, and the New Politics of Scarcity*, World Watch Paper, No. 132, Worldwatch Institute, Washington D.C., 1996.

Ransmeier, J.S. *The Tennessee Valley Authority: A Case Study in the economics of multiple purpose stream planning*. Vanderbilt University Press, Nashville, TN, 1942.

Repetto, R. "Skimming the Water: Rent Seeking and the Performance of Public Irrigation Systems." Research Report No. 4, World Resources Institute, Washington, D.C., 1986.

Rieu, T. and Gleyses, G. "Assessing the financial costs of water infrastructure and applications to a raw water supply system in Guadeloupe Island (French West Indies)." In International Commission for Irrigation and Drainage, *Guidelines for assessing existing and future costs of irrigation services.* International Commission for Irrigation and Drainage International Conference, 5th Meeting of the working group on Socio-Economic Impacts and Policy Issues, Montpellier, France, 15 September 2003.

Rodgers, C. and Hellegers, P.J.G.J. "Water Pricing and Valuation in Indonesia: Case Study of the Brantas River Basin.," EPT Discussion Paper 141, Environment and Production Technology Division, The International Food Policy Research Institute (IFPRI), August 2005.

Rogers, P., de Silva, R. and Bhatia, R. "Water is an economic good: how to use prices to promote equity, efficiency and sustainability." *Water Policy* 4 (2002): 1–17.

Rogers, P., Bhatia, R. and Huber, A. "Water as a Social and Economic Good: How to put the Principle into Practice." TAC Background Papers no. 2, Global Water Partnership, Stockholm, Sweden, 1998.

Saleth, R.M. "India." In Dinar, A. and Subramanian, A., eds. "Water pricing experiences: an international perspective." World Bank Technical Paper No. 386, Washington, D.C., World Bank, 1997, pp. 54–60.

Sampath, R.K. "Issues in Irrigation Pricing in Developing Countries." *World Development* 20 no. 7 (1992): 967–77.

Sampath, R.K. "Returns to Public Irrigation Development." *American Journal of Agricultural Economics* 65 (1983): 337–9.

Savenije, H.H.G. and van der Zaag, P. "Water as a economic good and demand management: Paradigms and pitfalls." *Water International.*, 27 (1), (2002): 98–104.

Savenije, H.H.G. and van der Zaag, P. "Demand Management and Water as an Economic Good, Paradigm and Pitfalls." Value of Water Research Report Series no. 8, IHE Delft, The Netherlands, 2001.

Savenije, H. "The socio -economic value of water: knowledge gaps and research questions in integrated water resources management." Paper presented at the UNESCO–WOTRO Conference on Water for Society, Delft, 8–10 November 2000.

Shapley, L.S. "A value for n person games." In Kuhn, H.W. and Tucker, A.W., eds., *Contributions to the theory of games*, vol. II, Annals of Mathematics Studies 28, Princeton University Press, Princeton, NJ, 1953, pp. 303–6.

Sinha, B. and Bhatia, R. *Economic Appraisal of Irrigation Projects in India.* Agricole Publishing Academy, New Delhi, 1982.

Southgate, D. “Best Practice Methods for Valuing Irrigation Benefits.” Contributing paper, World Commission on Dams, 2000.

Steenblik, R.P. “Subsidy Measurement and Classification: Developing a Common Framework.” In Organization for Economic Co-operation and Development, *Environmentally Harmful Subsidies: Policy Issues and Challenges*, Organization for Economic Co-operation and Development, Paris 2003.

Steenblik, R.P. “Subsidy Measurement and Classification: Developing a Common Framework.” Paper presented at the Organization for Economic Co-operation and Development workshop on Environmentally Harmful Subsidies, Paris, 7–8 November 2002.

Sur, M. and Umali-Deininger, D. “The Equity Consequences of Public Irrigation Investments: The case of surface irrigation subsidies in India.” Proceedings of the 25th International Conference of Agricultural Economists, Durban, South Africa, August 2003.

Sur, M., Umali-Deininger, D. and Dinar, A. “Water-related Subsidies in Agriculture: Environmental and Equity Consequences.” Organization for Economic Co-operation and Development workshop on Environmentally Harmful Subsidies, Paris, 7–8 November 2002.

SWWF (Second World Water Forum), *Forum report on water and economics of the Second World Water Forum*. The Hague, 2000.

Tardieu, H. “Socio-Economic Sustainability of Services Provided by Irrigation, Drainage and Flood Control Schemes in Water Resources Sector: An ICID Position Paper.” International Commission on Irrigation and Drainage, New Delhi, 2004.

Tardieu, H. “Irrigation and Drainage Services: Some Principles and Issues towards Sustainability: An ICID Position Paper.” *Irrigation and Drainage* 54 no. 3 (2005): 251–62.

Tiwari, D. “Determining Economic Value of Irrigation Water: Comparison of Willingness to Pay and Indirect Valuation Approaches as a Measure of Sustainable Resources Use.” CSERGE Paper GEC 98-05, The Centre for Social and Economic Research on the Global Environment, London, 1998.

Tiwari, D. and Dinar, A. “Role and Use of Economic Incentives in Irrigated Agriculture.” Unpublished paper. World Bank, Washington, D.C., n.d.

Tsur, Y. “Water Regulation via Pricing: The Role of Implementation Costs and Asymmetric Information.” Paper presented at the World Bank-sponsored Workshop on the Political Economy of Water Pricing Implementation, Washington D.C., 2008.

Tsur, Y. and Dinar, A. “On the relative efficiency of alternative methods for pricing irrigation water and their implementation.” *World Bank Economic Review* 11 (1997): 243–62.

Tsur, Y. and Dinar, A. “Efficiency and Equity considerations in Pricing and Allocating Irrigation.” Water Policy Research Working Paper 1460. The World Bank, Washington, D.C., 1995.

Umali, D.L. “Irrigation-Induced Salinity: A Growing Problem for Development and the Environment.” World Bank Technical Paper 215. Washington, D.C., 1993.

UN (United Nations), *Review of the Impact of Pricing Policies on Water Demand in the ESCWA Region with a Case Study on Jordan*, Economic and Social Commission for Western Asia, United Nations, New York, 1997.

UNCTAD (United Nations Conference on Trade and Development). *Subsidies to Services Sectors : A Neo Protectionist Distortion or a Useful Development Tool?* UNCTAD/DITC/TNCD/MISC/2003/7, United Nations Conference on Trade and Development, 2005.

UNEP (United Nations Environment Programme). *Proceedings of the Workshop on Addressing Existing Dams. Dams and Development Project.* United Nations Environment Programme, Nairobi, August 2004.

van Beers, C. and de Moor, S. *Public Subsidies and Policy Failures: How Subsidies Distort the Natural Environment, Equity and Trade and How to Reform Them* Edward Elgar, Cheltenham, 2001.

Vaidyanathan, A. "Report of the Committee on Pricing of Irrigation Water." Planning Commission, Government of India, New Delhi, 1992.

van Koppen, B., Moriarty, P. and Boelee, E. "Multiple Use Water Services to Advance the Millenium Development Goals." IWMI Research Report 98, International Water Management Institute, Sri Lanka, 2006.

Yang, H., Zhang, X. and Zehnder, A.J.B. "Water scarcity, pricing mechanism and institutional reform in northern China irrigated agriculture," *Agricultural Water Management* 61: 143–61.

Yaozhou, Z. and Bingcai, W. "Pricing of Irrigation Water in China." Paper presented at the international conference Irrigation Water Policies: Micro and Macro Considerations, Agadir, Morocco, 2002.

Young, H.P., Okda, N. and Hashimoto, T. "Cost Allocation in Water Resources Development." *Water Resources Research* 18 no. 3 (June 1982): 463–75.

Young, H.P., ed. *Cost Allocation: Methods, Principles, Applications*. North-Holland Elsevier Science, Amsterdam, 1985.

Young, R. "Measuring economic benefits for valuing water investments and policies." World Bank Technical Paper no. 338. The World Bank, Washington D.C., 1996.

Wateco, common implementation strategy for the Water Framework Directive (2000/60/EC), Guidance Document No 1, Economics and the Environment—The Implementation Challenge of the Water Framework Directive**,** Produced by Working Group 2.6—WATECO, Luxembourg: Office for Official Publications of the European Communities, 2003

World Bank. *Agenda for Water Sector Strategy for North China*, vol. 1, Summary Report. The World Bank, Washington D.C., 2001a.

World Bank. *China: Country Water Resources Assistance Strategy*. The World Bank, East Asia and Pacific Region, 2001b.

World Bank, World Resources Institute, United Nations Development Programme, United Nations Environment Programme "World Resources 1998-99" Oxford University Press, 1998 http://www.wri.org/wri/wr-98-99/irrigate.htm

World Watch Institute. *State of the World 2000*, Washington D.C., 2000.

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The Global Subsidies Initiative (GSI)
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The International Institute for Sustainable Development's Global Subsidies Initiative shines a spotlight on subsidies – transfers of public money to private interests – and the ways in which they can undermine efforts to put the world on a path toward sustainable development.

Subsidies have profound and long-lasting effects on economies, the distribution of income in society, and the environment, both at home and abroad. Subsidies have shaped the pattern and methods of agricultural production, even in countries that now provide few or no farm subsidies. They have encouraged fishing fleets to search farther and deeper than ever before, aggravating the problem of over-fishing. They have fueled unsustainable energy production and wasteful consumption patterns.

While subsidies can play a legitimate role in securing public goods that would otherwise remain beyond reach, they can also be easily subverted. Special interest lobbies and electoral ambitions can hijack public policy. When subsidies result in a fundamentally unfair trading system, and lie at the root of serious environmental degradation, the question has to be asked: Is this how taxpayers want their money spent?

The GSI starts from the premise that full transparency and public accountability for the stated aims of public expenditure must be the cornerstones of any subsidy program. In cooperation with a growing international network of research and media partners, the GSI is endeavouring to lay bare just what good or harm public subsidies are doing; to encourage public debate and awareness of the options that are available; and to help provide policy-makers with the tools they need to secure sustainable outcomes for our societies and our planet.

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