The Environment, Economics and Water Policies

Randy Stringer
Centre for International Economic Studies
Department of Economics
University of Adelaide

Comments welcome

Abstract

Water's unique physical properties, complex economic characteristics, important cultural features, and essential role in supporting all life on earth distinguish it from all other natural resources. These multifaceted characteristics mean that developing effective water policies involves economic, ecological, environmental, legal, and political considerations. In most societies, political considerations dominate water use decisions. Nonetheless, most water policy options are framed and discussed in economic terms. This papers examines how environmental economics contributes to this policymaking process. The paper outlines how economists have responded to the most recent wave of sustainable development concerns by adapting and expanding the neoclassical framework in ways that provide a compelling view and a practical basis for addressing water-related environmental concerns. It suggests that, whenever possible, incentive-based, market approaches to social goals, including environmental protection, offer the best hope for efficient and sustainable use of water resources.

Introduction and Overview

Almost any statement about water requires some kind of qualification. For example, while we can say that water is one of the most abundant resources on Earth, we know that less than 1 percent of the total supply is reliably available for human use. A fixed amount of annual rainfall implies a limited supply, but water can be stored and recycled so utilization rates can exceed water supply. Water is liquid, mostly, but it can also be a solid and a vapour. Drinking water is certainly essential for human survival, but water-related illnesses are the most common health threat in the Third World. An estimated 25 000 people die every day because of water-related sicknesses (UNEP, 1991).

One statement, however, needs no qualification: the existence of all life forms depends on water. The geosphere, the atmosphere, and the biosphere are all linked to water. Water interacts with solar energy to determine climate and transforms and transports the physical and chemical substances necessary for all life on Earth.

First draft of a paper to be presented at the AARES 41st Annual Conference, Gold Coast 20-25, January, 1997.

In recent years, water issues have been the focus of increasing global concern.[1] International, national and local organizations are becoming ever more active in water policy issues and debates, initiating, coordinating and participating in special programmes focusing on water resources. The theme highlighted by all these efforts is that water is an increasingly scarce and valuable resource. The principal concern is our failure to recognize and accept that water is in finite supply. The consensus is that growing water scarcity and misuse of freshwater pose serious threats to sustainable development.

Competition among agriculture, industry and cities for limited water supplies is already constraining development efforts in many countries (World Resources Institute, 1994; Bhatia and Falkenmark, 1992, Homer-Dixon et. al., 1993; UNCED 1992). As populations expand and economies grow, the competition for limited supplies will intensify, so will conflict among water users.

Even though water shortages are occurring throughout the world, misuse is widespread. Numerous studies document how small communities and large cities, agriculture and industries, developing countries and industrialized economies are all mismanaging water resources (Repetto, 1986; World Bank 1992; Gleick, 1993; Postel, 1993). Surface water quality is deteriorating in key basins from urban and industrial wastes. Groundwater is being polluted from surface sources and irreversibly damaged by saltwater intrusion. Overexploited aquifers are losing their capacity to hold water and lands are subsiding. Cities are unable to provide adequate drinking water supply and sanitation facilities. Waterlogging and salinization are diminishing the productivity of irrigated lands. Decreasing water flows are reducing hydroelectric power generation, pollution assimilation and fish and wildlife habitat. The very ecosystems responsible for producing water and maintaining our hydrological cycles are insufficiently monitored and poorly understood (Dasgupta and Mäler, 1995).

For years, national level economic policies and resource management systems inducing these long-term trends in water resource use were guided by socioeconomic objectives that seldom included explicit valuation of the environment, much less the concept of sustainable development. During the past decade or so, however, growing scarcity and heightened environmental concerns have forced governments and communities to rethink the role water plays in the economy, environment and society.

The purpose of this paper is to review some of the ways in which environmental economics has encouraged and influenced the design and implementation of water policies. The international community's increasing emphasis on sustainability presents today's resource policymakers with a set of new opportunities but also with some policy challenges. This paper attempts to contribute to the sustainability debate by examining how and under what conditions water policies work or fail.

The Water Sector and Sustainable Development

Within several years of publication of the Brundtland Report in 1987 (WECD, 1987), sustainable development had become a dominant feature of development thinking and policy dialogue. By the time delegates met at the United Nations Conference on Environment and Development (UNCED) in 1992, sustainable development implied that economic development must widen its focus from expanding production and increasing incomes to include sustainable management of ecological processes and environmental services.

UNCED concluded that scarcity and misuse of freshwater pose serious and growing threats to sustainable development and protection of the environment, emphasizing that human health and welfare, food security, economic development and ecosystems are all at risk, unless water resources are managed more effectively in the future than they have been in the past (UNCED, 1992).

Despite its message of harmony, however, the concept of sustainability raises tension between market-driven economic growth strategies, social pressures for a more equitable distribution of economic opportunities and the need to maintain environmental productivity, ecological services and biodiversity to fulfil future social aspirations. It is in this context that the international community has called for a new approach to the assessment, development and management of freshwater resources (ICWE, 1992). The proposed new approach involves the management of freshwater as a finite and vulnerable resource, the integration of fragmented sectoral water policies and programmes within the framework of national economic and social policy, and the recognition that water has economic value in all its competing uses.

For many, it is difficult to reconcile the concept of water as an economic good with the more traditional idea of water as a basic necessity and human right. Because water is essential to all life, policymakers often reject competitive market allocation mechanisms. Many societies believe that water has special cultural, religious and social values. Boulding observed that "the sacredness of water as a symbol of ritual purity exempts it somewhat from the dirty rationality of the market" (Boulding 1980).

The literature suggests that economists are not of one mind when asked to assess their preparedness to assist society with this new approach to environmental and sustainability concerns. Traditional neoclassical economists maintain that the economics profession was ready and waiting for the sustainability movement with a comprehensive analytical view of the nature of externalities and related market failures. This group points to a long-established set of prescriptive policies to deal with pollution (the introduction of surrogate prices); open access (clarification of property rights); and alternative uses of natural environments (economic valuation of environmental resources and services) (Cropper and Oates, 1992).

A second group distanced themselves from mainstream neoclassical economics, arguing that conventional economic analysis and policy measures are not only incompatible with sustainable development, they contribute to the problem (Daly, 1990). This group argues that neoclassical economists tend to offer impractical solutions to pressing environmental problems and dangerously misleading assumptions about human-nature interactions. They point out, for instance, how every elementary economics textbook contains a diagram illustrating the circular flow of goods and services across interdependent markets, neglecting to illustrate the flow of "goods" and "bads" between nature and humans.

A third group has responded to the most recent wave of environmental and sustainable development concerns by adapting and expanding the neoclassical framework in ways that provide a compelling view and a practical basis for addressing environmental degradation and intertemporal equity issues (Norgaard, 1988; Pearce and Turner, 1990; Solow, 1992, Young, 1992, Pantaouou, 1993; and Dasgupta and Mäler, 1995). This group includes a wide range of welfare, trade, development, and macroeconomists who have expanded greatly conventional neoclassical analytics by incorporating environmental perspectives into their specific fields of research. One example is the relatively new, but rapidly expanding literature analyzing how macroeconomic policies and the environment interact (Goldin and Winters, 1995; Gandhi, 1996; Munasinghe and Cruz, 1995). A second example is the now abundant theoretical and empirical research on trade and environment interactions (Anderson and Blackhurst, 1992, Low, P, 1992; Guevara, 1995).

In an assessment of operational and theoretical models used by economists to evaluate the relationship between human activity and nature, Colby (1990) categorizes these development strategies into five paradigms (see Table 1). Each paradigm contains different assumptions about human behaviour and about the role of nature and the environment. Each paradigm asks sep rate questions, emphasizes different evidence, addresses distinct threats, and relies on different analytical and modeling techniques for understanding how humans and nature interact.

The five paradigms include "frontier economics," at one extreme, with its emphasis on progress as infinite economic growth and an economic model characterizing a closed economic system; to "deep ecology" at the other extreme, emphasizing an anti-growth imperative and an economic model based on conservation of cultural and biological diversity. The three middle paradigms, "environmental protection," "resource management," and "eco-development," more fully capture the mainstream approaches of yesterday's and today's environmental economists and policies. Yet, any one approach maybe more appropriate to a specific case than the other four. In other cases, a mix drawn from several approaches maybe required.

In contrast to the conventional definition of environmental economics, Cobly's characterization of environment-economic paradigms is more useful for understanding the policy potential of environmental economics. The conventional approach to environmental economics constrains the analyses to two major issues: the valuation of environmental amenities and the regulation of polluting activities (Fisher and Peterson, 1976; Cropper and Oates, 1992).

The conventional approach also distinguishes natural resource economics from environmental economics. Natural resource economics applies dynamic control methods to the intertemporal allocation of renewable (regenerative resources in recent literature) and nonrenewable resources. Beginning with Hotelling (1931), natural resource economists have addressed the management of forestry, fisheries, energy and mineral resources, together with the extinction of species and the irreversibility of development.[2]

This paper maintains that practical policy solutions and realistic measures for addressing complex water resource problems requires a broad view of how economic theory analyses

Table 1 Distinctions between five paradigms of environmental management

Paradigm> Dimension	Frontier Economics	Environmental Protection	Resource Management	Eco-Development	Deep Ecology
Dominant imperative	Progress as infinite economic growth & prosperity	Tradeoff as in ecology vs economic growth	Sustainability as necessary constraint for green growth	Co-developing humans & nature	Ecotopia anti-growth constrained harmony with nature
Human-nature relationship	Very strong anthropocentric	Strong anthropocentric	Modified anthropocentric	Ecocentric	Biocentric
Dominant threats	Hunger, poverty, disease, natural disasters	Health impacts of pollution, endangered species	Resource degradation poverty, population growth	Ecological uncertainty	Ecosystem Collapse
Main themes	Open access free goods	Remedial defensive legalize ecology as economic externality	Global Efficiency Economize Ecology Interdependence	Generative restructuring, ecologize social systems, sophisticated symbiosis	Back to nature, biospecies equality simple symbioses
Property rights	Privatization	Privatization dominant, some public parks set aside	Global commons law for conservation of oceans, atmosphere, climate biodiversity	Global and local commons, private property for Intra/inter generational equity & stewardship	Private, plus common property set aside for preservation
Who pays	Property owners, public at large especially poor	Taxpayers	Polluter pays (producer & consumers)	Pollution prevention pays, income-index, environmental taxes	Avoid costs by foregoing development
Responsibility	Property owners	Development Decentralized Management Centralized	Toward integration across multiple levels	Private/public Institutional Innovations	Largely decentralized but integrated design
Analytic/modeling	Neoclassical, closed economic systems, reversible equilibria, production limited by human factors, natural factors not accounted for net present value, maximization, cost-benefit analysis of tangible goods and services	Neoclassical plus environmental impact assessment after design, optimum pollution levels, equation of willingness to pay and compensation	Neoclassical plus, natural capital, income, maximize UN system of national accounts, increased freer trade ecosystem & social health monitoring, linkages between population, poverty and environment	Ecological economics: biophysical-economic, open systems dynamics; socio-technical & ecosystem process design; integration of social economic & ecological criteria for technology; trade & capital flow regulation based on community goals; land tenure and income redistribution	Grassroots, bioregional planning, multiple cultural systems, conservation of cultural & biological diversity

Source: Adapted from Colby (1990)

the environment. This broad view means incorporating all the interrelated contributions made by welfare, trade, development, macro, environmental and ecological economists.

Water, Economics and Public Policy

In early civilizations, water played a relatively simple role. It was needed for drinking and it provided a fishing and hunting source. Over time, sedentary agricultural societies evolved and water use became more important. Families began settling near springs, lakes and rivers to supply livestock and crops with water, gradually developing technologies to divert water for irrigation and domestic purposes. Babylonian, Egyptian, Hittite, Greek, Etruscan, Roman, Chinese, Mayan, Incan and other empires constructed water delivery systems, such as long aqueducts to carry water to large cities (Yevjevich, 1992). In fact, until the middle of the twentieth century, most societies were able to meet growing water needs by locating reliable and relatively inexpensive sources.

When water is plentiful relative to demand, water policies, rules and laws tend to be simple and only casually enforced. As populations grow and economies expand, water sectors evolve from an "expansionary" phase to a "mature" phase (Randall, 1981). At some point during the expansionary phase, the financial and environmental costs of developing new water supplies begin to exceed the foregone economic benefits in the least-productive (marginal) uses. Reallocation of existing supplies, rather than capture of unclaimed supplies, then becomes the least-cost method to maximize benefits.

Scarcity is one of the most important issues in considering the various socioeconomic tradeoffs in allocating water among different users. Allocation policies and decisions determine who will have access to water, under what conditions, and what impact this will have on society and the economy. Human actions bring about water scarcity in three ways: through population growth, misuse and inequitable access (Homer-Dixon, et. al. 1993). Population growth contributes to scarcity simply because the available water supply must be divided among more people. Every country has a more or less fixed amount of internal water resources, defined as the average annual flow of rivers and aquifers generated from precipitation. Over time, this internal renewable supply must be divided among a larger number of people, eventually resulting in water scarcity.

When annual internal renewable water resources are less than 1 000 cubic meters per person, water availability is considered a severe constraint on socio-economic development and environmental protection. Most countries facing chronic water scarcity problems are in North Africa, the Near East and Sub-Saharan Africa. Countries with less than 2 000 cubic meters per person face a serious marginal water scarcity situation, with major problems occurring in drought years. By the end of the 1990s, water availability is expected to fall below 2 000 cubic meters per person in over 40 countries.

In many countries, while scarcity is less of a problem at a national level, serious water shortages are causing difficulties in specific regions and watersheds. Notable examples include northern China, west and south India and parts of Mexico.

People also cause water scarcity by polluting and overusing existing supplies. Water pollution is arguably the greatest water-related environmental problem in the developing world today. Nearly one billion people are exposed to contaminated drinking water.

Providing easier access to safe drinking water significantly improves health conditions. Personal hygiene increases when water availability rises above 50 litres per day (which generally means that it must be delivered to the house or yard).

An estimated 1.7 billion persons contend with inadequate sanitation facilities (World Bandk, 1992). This lack of sewage collection and treatment is a major source of surface and groundwater pollution. The 1992 World Development Report estimates that providing access to safe water and adequate sanitation could result in two million fewer deaths from diarrhoea among young children and 200 million fewer episodes of diarrhoeal illnesses each year.[3] Contaminated and polluted water kills, and debilitates, reducing physical capacity, lowering productivity, stunting growth, and inhibiting learning. These water-related conditions reduce learning capacity, school performance and school attendance of children, and increases the work days lost to sickness, lowers earnings, and shorten work lives of adults.

Overusing water supplies is regarded as the consumption of the resource's "capital". For instance, an aquifer represents resource capital, providing what is generally a renewable source of water that can be tapped for human consumption. Sustainable use of the aquifer leaves the "capital" intact so that future generations can continuously use the renewable portion. If pumping is greater than recharge, the aquifer is depleted and the "capital" is consumed.

In some circumstances, "mining" groundwater may be rational. However, pumping aquifers faster than the recharge rate increases pumping costs and eventually results in a water source too depleted to serve as a supply. Overuse of groundwater has become a major problem in the western United States, Indonesia, Thailand, China, India, Mexico, North Africa, the Near East and in many island countries where seawater intrusion results. The land above overpumped aquifers may settle or subside, resulting in widespread structural damage in extreme cases. Bangladesh and Mexico City are well-known examples.

Finally, a shift in access or distribution can concentrate water resources among one group and subject others to extreme scarcity. In many cities of the developing world, large numbers of people depend on water vendors, and may pay 100 times as much as public utilities charge (Bhatia and Falkenmark, 1992). Large numbers of urban poor pay much higher prices and a much larger share of their income for water than families with access to a city water system. In some large cities, the poorest families spend up to 20 percent of their income on water. When the cost is so high, these families use little water for washing and bathing, which results in serious health problems.

Older elementary economic textbooks explain the conceptual puzzle--why diamonds with so little utility are expensive, while freshwater which is so basic to life is cheap. More recent texts leave water out of these vignettes. Like fresh air, it was once considered a classic free good; now it is scarce and, while not expensive, it is at least acknowledged to be valuable.

Often the cheapness of water is more apparent than real. It is a free good not because water provision is costless - obviously this is far from true. Governments have chosen to charge less than full costs for water services for one or more reasons. These subsidies are now coming under scrutiny. Most natural resource policymakers now acknowledge that past failures to recognize water's economic value and the real cost of service provision have led to wasteful and environmentally-damaging uses.

A water sector in the "mature" phase is characterized by rising marginal costs of providing water and increasing interdependencies among users. Conflicts over scarcities and externalities begin to arise. These conflicts eventually become so complex that elaborate management systems are needed to resolve disputes and allocate water among different users and economic sectors.

Developing effective water resource policies to address these issues is troublesome for a number of reasons. First, water has important cultural features, unique physical properties, complex economic characteristics, and a unique role in ecosystems that distinguish it from all other resources. Throughout the world, water is treated as more than an "economic" commodity. In many cultures, goals other than economic efficiency play an unusually large role in selecting water management institutions. Some religions, such as Islam, even prohibit water allocation by market forces.

Second, water management is administratively complicated. It involves legal, environmental, technological, economic and political considerations. Water resource management depends on society's ability to establish an appropriate legal, regulatory and administrative framework. For example, markets depend on a system of enforceable, secure and transferable property rights, including the right to exclude other users. In most societies, political considerations dominate decisions on water resource use. Nonetheless, most policy options are framed and discussed in economic terms.

Third, water's physical characteristics further complicate effective policy efforts, especially its weight and mobility. Water is so heavy that the value per unit weight tends to be relatively low. Unlike petroleum, the costs of transporting and storing water are generally high relative to its economic value at the point of use. Water is also difficult to identify and measure because it flows, evaporates, seeps and transpires. This evasive nature means that exclusive property rights which are the basis of a market economy, are hard to establish and enforce.

Fourth, both efficient markets and efficient policy interventions are necessary to manage water's diverse benefits and its diverse environmental problems (See Table 2). Water provides commodity benefits, waste assimilation benefits, environmental service benefits and aesthetic and recreational benefits.[4] Individuals derive commodity benefits from water by using it for drinking, cooking and sanitation. Farms, businesses and industries obtain commodity benefits by using water in productive activities. Assimilation benefits are derived from water's capacity to process, dilute and carry away wastes.

Water also provides ecological and environmental services. Water's ecological services may be divided into products (that can be used or sold) and functions (that contribute to ecosystem maintenance). Wetland products include food, fuel, building materials, tourism, transportation networks, biodivesity and genetic stock, to name a few. Wetland functions include purifying, filtering and regulating water supplies, protecting coasts, and providing a habitat for wildlife.

Commodity benefits represent private good uses of water that are often exclusive and rival in consumption. Water's environmental benefits, waste assimilation and aesthetic values are closer to being public goods (non-rival in consumption and non-exclusive) than private goods.[5] Table 3 illustrates the range water's private to public goods characteristics.

If water as a commodity, or the economic system in which water is used, meet the preconditions for a market system, government interventions emphasize "incentive structures" and "rules." The most important rules are the laws governing the establishment of property rights to water and the enforcement of contracts. On the other hand, public policy interventions are required to satisfy social goals such as ameliorating income inequalities, promoting development in disadvantaged regions, regulating private activities that harm the environment, and controlling undesirable effects of a private profit-oriented monopoly.

Table 2 Water-related Environmental Issues

Water-related Environmental Issues	*Productivity*	*Health*	*Amenity*	*Existence*
Loss of wetlands				
Functions	x	x	x	x
Products	x			
Groundwater depletion/contamination	x	x	x	
Surface water pollution	x	x	x	x
Wildlife	x		x	x
Salinization/waterlogging	x	x		
Global warming	x	x	x	x
Biodiversity		x		
Water erosion	x	x	x	x

The misuse and overuse of water resources are related to distorted, malfunctioning, and missing markets. Water markets are incomplete or missing due to externalities, public goods characteristics, policy distortions, transactions costs, uncertainty, lack of knowledge, insecure property rights, and irreversibility.

Even in the event of market failures, nonmarket approaches may not necessarily yield a better solution. In many cases, nonmarket responses to market failures lead to less than optimal outcomes. In particular, some government agency performance incentives result in a divergence from socially preferable outcomes both in terms of allocative efficiency and distributional equity criteria.[6] The problem areas relevant to water sector services are:

(1) "Water products" that are hard to define. The outputs of non-market activities are difficult to define in practice and to measure independently of the inputs that produced them. Flood control or amenity benefits of water storage reservoirs are examples of water system outputs that are hard to measure.

(2) Private goals of public agents. Internal goals of a public water agency, or "internalities," and the agency's public purposes provide the motivations, rewards and penalties for individual performance. Examples of counterproductive internal goals include budget maximization, expensive and inappropriate high-tech solutions and outright non-performance of duties. In addition, agencies may adopt high-tech solutions or "technical quality" as goals in themselves. For example, they may recommend sprinkler or drip irrigation systems when other less expensive but reliable methods are more economical. Finally, irrigation agency personnel may be persuaded, by gifts or other inducements, to violate operating rules for a favoured few (Wade, 1982).

(3) Spillovers from public action. For example, public sector irrigation projects can also be a major source of externalities. Salinity and waterlogging of downslope lands can occur just as easily from inappropriately managed public irrigation projects as from private irrigators.

(4) Inequitable distribution of power. Public sector responsibilities, however noble their intent, may not be scrupulously or competently exercised. Yet the monopoly control of water supplies by public agencies provides certain groups or individuals with so much power over the economic welfare of water users that procedures to protect those of limited influence should be of prime importance.

Fifth, many water management problems are site specific and so elude uniform policy treatment. While water consumption and quality requirements depend on local populations and development levels, local water availability usually changes throughout the year with climatic variations and over longer cyclical swings. These supplies may be highly variable and unpredictable in time, space and quality. Water projects that attempt to compensate for extreme seasonal variations such as floods and droughts frequently require enormous investments. The economies of size are so large in these cases that unit costs continue to fall over the range of existing demands; a classical natural monopoly.

On the other hand, most economies of size for pumping groundwater are achieved at relatively small outputs, so competitive markets can operate efficiently. Aquifer management is often complicated, however, by the aggregate impact of the actions of many individuals. Even though each individual may have a negligible impact when taken alone, the sum total can be of major importance. One example is the rapid spread of tubewell irrigation in south Asia. One tubewell has little effect on the total water supply, but thousands of tubewells can quickly deplete an aquifer. Establishing effective policies to regulate these many small, scattered decision-makers has proved to be exceedingly difficult.

Moreover, aquifers are usually hydraulically linked with rivers or streams--part of a river's volume may come from underground flows, and rivers may replenish groundwater stocks. This hydraulic linkage is affected when an aquifer is heavily pumped. A lowered groundwater table may draw water from a connected stream, reducing its flow to surface water users.

In the late 1960s, Kneese and Bower (1968) were among the first environmental economists who argued that water cannot be analyzed in isolation, nor can it be addressed with policy proposals that fail to consider how a region's water resources are interconnected. Today, it is at least widely recognized (if not always practiced) that water sector polices require an integrated and broad approach because of water's special nature as a unitary resource: rain, rivers, lakes, groundwater and polluted water are all part of the same resource, making global, national, regional and local actions highly interdependent (Rogers, 1992).

Water use in one part of the system alters the resource base and affects water users in other parts. Dams built in one country frequently reduce river flows to downstream countries for years, affecting hydroelectric and irrigation capacity. When a city overpumps a groundwater supply, stream flows may be reduced in surrounding areas; when it contaminates its surface water, it can pollute groundwater supplies as well.

Water policies, laws, projects, regulations and administrative actions often overlook these linkages. Governments generally organize and administer water sector activities separately; one department is in charge of irrigation; another oversees water supply and sanitation; a third manages hydropower activities; a fourth supervises transportation; a fifth controls water quality; a sixth directs environmental policy and so forth.

These fragmented bureaucracies make uncoordinated decisions, reflecting individual agency responsibilities that are independent of each other. Too often, government planners have developed the same water source within an interdependent system for different and competing uses. This project-by-project department-by-department and region-by-region approach is no longer adequate for addressing water issues. Water managers are increasingly being called upon to review conditions, problems and progress in the overall water sector.

In the mid-1950s, Libsey and Lancaster (1956) illustrated how the correction of a single market distortion without correcting other sources of market failure can produce a pareto-inferior resource allocation. An important development in the use of environmental economics over the past five years has been research focused on how the overall water sector is linked to the national economy. These research efforts are helping us to better understand the welfare implications of independent, corrective actions. Equally important has been an increased understanding of interactions between water, sectoral and environmental policies and how these policies collectively influence water use across different sectors; between local, regional and national levels; and among households, farms and firms (Weinberg and Kling, 1996).

Linking the Water Sector with the National Economy

In Hirschman's classic analysis of public investment decisions, he describes the "centrality of side-effects", noting that many investment decisions would never have been undertaken if the decision-makers had fully visualized all of its consequences"

(Hirschman, 1967). This statement also applies to water policies. Policymakers too often confront water policy issues one at a time, stating policy objectives in single dimensional terms. This approach presents difficulties because a policy aimed at achieving a single objective usually has unintended and unrecognized consequences. During the past decade, economists have made increasing use of CGE models to simulate economic and environmental interactions, helping us to better understand intersectoral linkages and avoid potentially costly and damaging policies.[7]

Macroeconomic policies and sectoral policies not aimed specifically at the water sector can have a strategic impact on resource allocation and aggregate demand in the economy (Girma, 1992, Munasinghe, and Cruz, 1995; Panayotou and Hupe, 1995; Gandhi, 1996). A country's overall development strategy and use of macroeconomic policies -- including fiscal, monetary and credit market reforms; trade liberalization; public sector reforms; exchange rate adjustments; and tax, price controls and subsidy reforms-- directly and indirectly affect demand and investment in water-related activities.

An obvious example is government expenditures on irrigation, flood control or dams. A less apparent example is trade and exchange rate policy aimed at promoting exports and earning more foreign exchange. For example, as a result of currency depreciation, prices in domestic currency of a country's high-value, water-consuming export crops may increase. If additional policy changes reduce export taxes, farmers are provided with an even greater incentive to invest in export crops, including investments in irrigation.

National development strategies can influence water allocation and use in other direct ways. In the case of a food self-sufficiency strategy, the government may subsidize water-intensive inputs to encourage farmers to produce more rice. By providing financial incentives to rice producers, the government is influencing the demand for water and private irrigation investment through price policies.

Apart from the direct effects on water use resulting from such price policies, the increased demand for irrigation water also has intersectoral, intrasectoral, distributional and environmental implications. The agriculture sector is provided with an economic advantage in access to water vis-a-vis the industrial sector (intersectoral); water used for rice gains an economic advantage over water used for other crops (intrasectoral); rice producers with more land and access to water gain over those with less land and water (distributional); and increased pesticide and fertilizer use are likely to affect water quality (environmental).

Sectoral policies affect water use and allocation in other sectors in a variety of ways. For example, in the western United States, 70 to 80 percent of the region's water yield results from snowmelt from the high elevation forests, much of which is under public jurisdiction. Water yields are significantly affected by timber harvest policies on these lands. Rangeland management policies on lower elevations also alter vegetation conditions and thus affect the rate of evapotranspiration, affecting streamflow and groundwater recharge (Saliba, et.al., 1987). In such cases, it is important for downstream city water managers to recognize, understand and become involved in the decisions of other sectors such as livestock and forestry.

With the continuing importance of structural adjustment and stabilization programmes, many developing countries are implementing fundamental changes in macroeconomic and sectoral polices. Typical adjustment programmes call for a greater reliance on markets, more open trade, fiscal austerity, and a phase out of producer and consumer subsidies (input and product markets).

Budget-reducing measures imply increased competition between and within sectors for funding new water projects. In this situation, the overall economic, social and environmental implications of choices must be carefully addressed. For example, when the government must choose between financing either an irrigation project or a hydroelectric power project, there is an additional social opportunity cost of the irrigation water in countries dependent on imported energy sources. At the same time, when water scarcity keeps some farmers on uneconomic lands such as steep watersheds, the country suffers twice. Once in terms of reduced production over that possible with irrigation; and again, in terms of erosion and resource depletion, with the erosion possibly shortening the life of existing water works (Bromley, et.al, 1980).

In most countries, pressures have increased not only to modify investment allocations but also to recognize and accommodate new demands for water. The direct implications for water managers include fewer capital investments in new water projects, the elimination of irrigation subsidies, increased efforts at cost recovery, and more emphasis on demand management to improve the efficiency of existing supplies.

Environmental Policy and Water Use

To help select the most appropriate environmental policy option or programme alternative, economists tend to divide the water sector into supply-side and demand-side components. The supply-side approach is structure-oriented-- investments in water projects are combined with engineering and technical expertise to make systems operate effectively. For most of the twentieth century, policymakers focused their attention on the supply side. Economists evaluated these water projects and policy options through cost-benefit analysis (CBA).

In the past two decades, economic theory has made significant advances in our capacity to value environmental assets, including use values (direct and indirect) and non-use values (options values, bequest values and existence values).[8] In their 1976 survey of environmental economics, Fisher and Peterson lament the inability of economists to provide reliable valuations despite diligent efforts. Some fifteen years later, in their survey of environmental economics, Cropper and Oates (1992) note considerable progress in two fronts: (1) the development of indirect market methods to evaluate the relationships between environmental quality and marketed goods; and (2) the direct questioning of individuals about their valuation of environmental goods--the contingent valuation approach.

Today, policymakers have a practical set of options available for pricing and valuing environmental assets and determining alternative uses of water's competing uses.[9] These improved environmental pricing techniques provide policymakers with more accurate information: for setting environmental taxes and subsidies; making decisions based on environmental accounts of national income; producing natural resource damage assessments; and carrying out CBAs of water policies, projects and regulations (OECD, 1995).

Aided by this increased ability to price water's environmental benefits, policymakers are also emphasizing non-structural approaches to water management. A non-structural policy approach encompasses demand management, scientific research, education and persuasion to coordinate human behaviour. These demand-side policies attempt to address water problems such as water quality degradation, overexploitation of aquifers and the decreasing availability of water flows to meet non-consumptive water uses (hydroelectric power, pollution assimilation and fish and wildlife habitat).[10]

Demand-side water policies attempt to coordinate human activities and control environmental degradation through non-market institutions like property rights and incentive structures. Altering the institutional system of permissions, restrictions, incentives and penalties can compel consumers to do what they otherwise might not do.[11] Non-market institutions play an important role in demand management by defining the incentives, disincentives, rules, rights and duties (including informal customs and formal legal systems) that guide human activities and encourage conforming behaviour (Bromley, 1989). Thus property rights are part of an institutional arrangement governing economic activities of water use.

Two factors influence significantly the form of water institutions in a society: the relative scarcity of water and the transactions costs required to establish and enforce water rights. While scarcity is both supply and demand-dependent, the relative human pressures on the demand side are probably the most important. Transactions costs are the resources required to obtain information, negotiate agreements on property rights and police these agreements. Water supply and demand characteristics make transactions costs relatively high and the value of water relatively low compared to other resources or commodities.

Many economists are trying to find ways to improve institutional performance. Research to date suggests that institutions respond to the same types of incentives as do innovators of technological change (Ruttan, 1978; Runge, 1987). When water is plentiful relative to demand, laws governing water use tend to be simple and enforced only casually. Where water is scarce, more elaborate institutional systems evolve. Higher population and income levels and technological advances have only recently prompted societies to establish formal water use and quality management systems.

Establishing an institutional structure for allocating water is a fundamental role of social policy. The choice of structure is ultimately a compromise between the physical nature of the resource, human reactions to policies and competing social objectives. Not surprisingly, different cultures make tradeoffs based on the relative importance of their particular objectives. Many countries try to balance economic efficiency (obtaining the most value of output from a given resource base) and fairness (assuring equal treatment). Individual freedom, equity, popular participation, local control and orderly conflict resolution are other important objectives which societies must juggle when choosing a structure for water allocation.[12]

In the "ideal" market-based water allocation system, entitlements (water rights) are well-defined, enforced, transferable and confront users with the full social cost of their actions. This type of market-dependent institutional arrangement requires security, flexibility and certainty. Security refers to protection against legal, physical and tenure uncertainties. A system is flexible if allocations between users, uses, regions and sectors can be changed at low cost. Flexibility implies that changes in demand are accommodated easily by reallocating water to higher-valued uses as they emerge. Certainty is also necessary: water use rules must be easy to discover and to understand.

Prices and Water Allocation

In practice, market forces rarely establish prices for water. Instead, prices are set by publicly-owned supply agencies or regulated private utilities. Water prices impact on efficiency, equity and environmental services. Countries are increasingly adopting the full cost principle, which employs market and nonmarket incentives to encourage all users of resources to pay for the full cost of their use. This principle is based on the presumption that all humanity has a right to a reasonable safe and healthy environment. This section reviews the common pricing schemes applied to water in light of the full cost principle.

Rate-setting can be evaluated within a multiple objective framework, in which allocative efficiency, equity of income distribution and fairness in apportioning costs, and environmental degradation each play a role in evaluating pricing policies. Secondary criteria of simplicity, administrative feasibility and stability are also taken into account.

The most commonly employed pricing policy for water is a flat rate charge, designed primarily to recover costs. Flat rates are not set according to the volume received, although some proxy for volume usually provides the basis for the charge. In agriculture, the most frequent basis for a water charge is the area irrigated. For residential use in the industrialized world, flat rate charges have been based on the number of residents, the number of rooms, the number and type of water-using fixtures or on measures of property value.

Economists criticize flat rates because they do not include incentives for rationing water in line with willingness to pay and the full cost principle. Such schemes are, however, simple to administer and assure the supplier adequate revenue. The high cost of installing and monitoring meters is suggested as the main reason for staying with the flat rate approach. This argument is convincing in cases where water is plentiful, supply costs are low and managers doubt the rationing effects of volumetric pricing. In other cases, water managers are turning to volumetric pricing to address water scarcity and environmental problems and the high costs of developing new supplies.

Societies interested primarily in allocative efficiency (maximizing net social product) as the goal for a pricing scheme advocate marginal cost pricing. When prices are set at marginal cost, rational consumers demand water as long as willingness to pay (demand) exceeds the incremental costs. But application of marginal cost pricing encounters a number of obstacles. One problem is the variety of definitions of the appropriate marginal cost concept, particularly whether to use a short-run (variable cost) concept, or a long-run full-cost approach. A long debate ensued over the "short run marginal cost" pricing proposal stemming from welfare economists' work in the 1930s. For example, Coase (1971) strongly objected to setting utility prices at short run marginal costs, especially where marginal costs are below average cost (thereby incurring a deficit and requiring public subsidy). Coase also criticized the absence of a market test to determine whether users were willing to pay full cost of supplying the commodity; the redistribution of income in favour of users of decreasing cost industry products; and the impetus toward centralization of the economy.[13]

The ability to pay principle rests heavily on the equity criterion. Water charges are dependent on income or wealth, rather than costs. This principle is the most common basis for setting irrigation rates throughout the world, and is also regularly applied to village water supplies in developing countries. The ability to pay approach bears little relation to costs, since no allocative test of willingness to pay is provided. This ability to pay concept is inherently subjective, and political pressures frequently arise to set the formula in ways that distribute wealth from taxpayers to water users.

In many places throughout the world, water is only now becoming scarce enough to justify the tangible and intangible costs of establishing formal pricing systems. Flat rates could satisfy repayment requirements in the absence of serious shortages. However, when the signals of water scarcity are absent, pressures arise for structural solutions to satisfy incorrectly perceived water "needs".

The inevitability of scarce water supplies suggests the eventual adoption of multipart rate schemes which reflect the opportunity costs of water and other resources. The literature describing the most desirable form for water markets and the literature dealing with water pricing have converged on the notion of a pricing system which reflects the opportunity cost of water via the mechanism of transferable water entitlements (Randall, 1981, Boggess, et. al., 1993; Rosegrant, 1993, Rosegrant and Binswanger, 1993). At present, Chile is the only country with a comprehensive water allocation system that establishes tradeable property rights (Rosegrant and Bisnwanger, 1993).[14]

Because it deals with the complex interaction between human society and the physical environment, aquifer management presents an extremely difficult problem of policy design. Collective policy decisions of two types must be addressed in the management or regulation of overexploited aquifers. For one type, termed "managing the water," decisions must be made on (1) the appropriate annual rate of pumping; (2) the geographic distribution of pumping; and (3) whether to augment water supplies and/or whether to artificially recharge the aquifer. The other important type of policy decision is "coordinating the pumpers" to determine (1) the institutions and policies that divide the extraction rate among potential individual users and user classes and influence pumper behaviour; and (2) how rules for limiting pumping are monitored and enforced.

Three broad types of institutional arrangements have been proposed for managing aquifers: prices and charges, quantity-based controls and exchangeable permits.

(1) *Prices and charges to control pumping*: Charging pumpers is one potential method of achieving economically efficient extraction rates. An appropriately scaled charge confronts pumpers with both the foregone user cost and the external cost (from increased

pumping costs) imposed on neighbouring pumpers. This type of water charge internalizes user costs and external costs and achieves an optimal extraction rate.

In the case of aquifer management, this approach faces one important difficulty--pumpers are imposing costs on themselves, (that is, they are reciprocal). The reduction in use would be at the expense of redistributing rents to the taxing authority. It would dissipate net income to the aquifer exploiters as quickly as an open access regime, although the total net rents would be increased

(2) *Quantity-based approaches*: Quantity-based control mechanisms range from simple well permits to exchangeable pumping entitlements. Well and pump permits grant the right to install and operate a well of a particular capacity. Irrigation permits frequently identify the lands on which well water could be used, restricting transport of water to other sites. They are relatively easy to monitor and are reasonably palatable to pumpers who strongly reject more stringent regulatory devices. On the other hand, permits are most effective before problems have become severe and complex: when preventing new wells and pumps solves the problem, or when pumped water is not exported away from the area overlying the aquifer. In more serious cases, where all existing users must reduce annual extractions, regulating rates of withdrawals must be considered.

A pumping "quota" is a precise quantity control mechanism. The quota specifies a fixed annual rate of extraction to each water user. The initial quantity might be assigned in proportion to use in a base period, (which could set off a pumping race to establish initial rights), or be based on the proportion of land owned overlying the aquifer. The technology for metering withdrawals is neither complex nor expensive, so if the pumpers are willing to be metered, regulatory monitoring and enforcement need not be difficult. In principle, pumping quotas e no different than conventional surface water rights, which entitle owners to fixed sh s of each year's available flows.

(3) *Transferable pumping entitlements*: When a fixed quota is too inflexible in the face of changing water stocks and demand conditions, transferable pumping entitlements are an alternative. The pumping entitlement can be divided into two parts: one component providing a claim to the stock of water, and the other to the annual recharge. Both claims may vary from year-to-year, with allotments set by the groundwater authority. Annual rights to the basic stock would vary according to current and anticipated economic and hydrologic conditions (including energy and commodity prices, interest rates and the remaining stock of groundwater). Rights to the natural recharge and return flows from human uses could be set to reflect a moving average of estimated recharge in recent years.

Preserving Water Quality

Pollution is an inevitable and pervasive phenomenon in the modern world. Human production and consumption activities generate residuals by extracting and processing raw materials into consumer goods. The materials balance principle, derived from basic laws of physics regarding the conservation of matter, asserts that over the long run, the mass of residuals discharged to the environment equal the mass of materials originally extracted from the environment to make consumption goods. The environment's importance as an assimilator of residuals is equal to its importance as a source of materials.[15]

Kneese (1962) appears to be the first economist after Pigou to treat pollution externalities analytically and express serious concern about water pollution. Kneese's study on water quality management incorporated the Pigouvian externality framework and a recognition of the rage of management alternatives.

Control of point source water pollution

The most frequently used approach to point source pollution control is government-imposed standards or targets for ambient water quality. Standards are implemented by setting discharge levels for each type of pollutant, for each polluter or for each polluter class. The environmental agency monitors compliance, and often is empowered to impose penalties on violators. Several different approaches to specifying target discharge levels have been tried: (a) limits on maximum rates of discharge from a pollution source; (b) specified percentage removal of pollutants from emissions; (c) requirements to implement some technology package ("best available technology").

Many believe that the regulatory approach has proven to be an effective and equitable means for reducing pollution discharges and raising environmental quality. The bargaining process that precedes the selection of exact control packages has provided flexibility and encourages voluntary compliance by polluters. Most regulatory agencies and legislatures are comfortable with the approach.

Environmental economists have long objected to the standards for most situations. Direct regulations appear to provide solutions to pollution control that are more costly to society than other means. In particular, an incentive-based approach is more likely to find the pollution discharge rate that minimizes the total cost to society. More general objections arise from government failure: regulations may be poorly conceived and arbitrary or manipulated for purposes unrelated to their original intent.

An alternative approach to pollution control regulations are decentralized incentives and disincentives. A key assumption of the incentives approach is that social policy regarding pollution control should encourage the selection of the least-cost set of pollution control options, where pollution damage costs as well as residuals treatment costs are both considered.

An environmental tax based on the "polluter pays" principle, is one incentive option adopted and endorsed by the OECD in the 1980s. The regulatory authority imposes a fee or tax on each unit of the contaminant discharged. The charge is set to represent the economic value of the damages caused by the pollutant. The effluent charge rises with increased levels of discharges. Polluters are, under the emissions tax approach, free to respond to the charge as they choose. All firms would find it in their interest to seek changes in technologies and/or in treatment of discharges which reduce the social costs of coping with the problems of residuals disposal. In effect, the polluter is faced with an incentive to economize on the use of scarce environmental assimilative capacity.

Even after several decades of advocacy by economists, effluent taxes are seldom selected as pollution control policy instruments. The principal objections come from polluting industries themselves, who object to a charge for environmental services previously received free, and point to adverse profit and employment impacts. Their concerns are also based on a fear that taxes might go beyond the stage of taxing to attain the optimal degree of discharges, to punitive taxation for pollution itself. In addition, the tax may raise the cost of firms, not only by the amount of the tax, but also by the costs of treatment to avoid part of the tax.

Another disadvantage is the difficulty in the authority's ability to measure the value of external costs or damages (the "damage function"). More philosophical objections arise on essentially ethical grounds. One view is that pollution control policy should focus on minimizing damages to third parties, and ignore the economic model (which balances incremental gains to sufferers against incremental treatment costs. A more subtle objection is based on the fear that a tax, by putting a "price" on the environment, sends the message to polluters that the environment is merely another economic commodity to be bought and sold.

The concept of marketable effluent permits, was first introduced by Dales (1968) address water issues. Marketable permist are a variation on the decentralized, incentive-based approach. A central authority, perhaps for a specific river basin, decides on the total permissible pollution discharges. Permits equivalent to that total would be issued, subject to the requirement that no discharges are allowed without a permit. The initial issue of permits might be based on historical discharges (or a fraction) or via an auction to the highest bidder. Once issued, the permits would be marketable and the opportunity costs of discharge versus treatment would influence behaviour. The authority could fine-tune water quality by withdrawing permits or by issuing more.

The permit system creates the same incentives to reduce emissions and find low-cost abatement technologies as the effluent tax. Polluters whose cost of emission reduction is relatively expensive would buy additional permits. Those with less costly opportunities for reducing discharges could adopt new techniques and profit by selling some permits. Potential new polluting industries must enter the permit market, buying permits and replacing other dischargers. The price of permits also provides a signal to new entrants about the scarcity of environmental quality relative to other basins and to technological abatement opportunities.

In addition to the economic efficiency (cost-effectiveness) argument, a principal advantage of the tradeable permit approach is that it represents a natural extension to the pollution permit system already existing in many nations. Objections are similar to those concerning effluent taxes. Critics worry about one firm cornering the permit market to reduce competition for its products. Once again polluters resist having to pay for services previously obtained free. Environmental interests are dubious about a policy which grants rights to what they regard as a reprehensible activity.

Nonpoint Pollution Control Options

Policy options to control non-point pollution present special difficulties because of the great variety of sources and pollutants. The primary source of nonpoint pollutants is the agricultural sector. Urban storm drainage, leakage from buried fuel tanks, and subsurface and surface mining are other contributors. Non-point source pollution is also characterized by its episodic nature. Occasional heavy rainfall or snowmelt typically is the trigger, in contrast to the more even flows of discharges by point sources. These characteristics of source type and timing imply that a variety of control technologies may be required for effective abatement.

Another complex aspect of nonpoint pollution control arises from the nature of human activities. For example, the pollution arising from a farmer's land depends not only on the rainfall patterns and the land characteristics (slope and soil texture), but on numerous prior land use and production decisions, including choice of crops, tillage practices, and pesticide and fertilizer use. The farmers' production choices are, in turn, influenced by market prices for inputs and products, as well as by government price and income support programs. In fact, one source of agriculture pollution is government policies which make certain crops overly attractive. Successful policy interventions must change those aspects of farmers' decisions which are the source of pollutants.

Policy options for nonpoint pollution control are classed as cognitive, regulatory or incentive-based. Cognitive (voluntary) approaches, using education, moral persuasion and technical assistance, have been tried in some countries, but progress appears elusive. Cognitive approaches are attractive because of low economic and political costs. Several factors account for their limited success. Private costs necessary to change land use practices are not trivial, while private gains may not be obvious. Because of the uncertain linkage between changing production decisions and improving water quality (often at distant locations), individuals are little inclined to try new approaches (Harrington et. al., 1985).

Regulatory policies call for specific actions or prohibitions on those causing water quality degradation. One approach is to use "design standards," which specify actions to be taken, (such as a management plan for sediment control) or actions prohibited (such as avoiding certain cropping practices on highly erodible lands). "Performance standards", in contrast, place limits on the rate of pollution discharge to the water body. In this case, interference with land use practices would be only in response to observed violations (Anderson and Bishop, 1985).

Neither technique is without limitations. Design standard regulations are easier to enforce. However, they may be unnecessarily costly because their general application may impose costs on some who contribute little to the problem. Performance standards, in principle at least, focus more directly on the pollutant source, but are difficult to enforce. Because accurate measurement of discharges (particularly from small farms) are nearly impossible, disputes over actual sources of pollutants are unending.

The major alternative to regulatory policies are various incentive methods. Incentive policies include several specific mechanisms, including taxes, subsidies and trading policies (Segerson, 1990). Taxes or fees could be levied on either inputs or pollution outputs. For example, extra charges have been imposed on agricultural fertilizers in Sweden, with proceeds used to fund water quality monitoring. Higher costs are expected to reduce fertilizer application rates and therefore water pollution. Taxes are unlikely to be set high enough to significantly affect land use, because of the adverse income effects.

Alternatively, charges might be levied on pollution by imposing an "effluent charge". The technical and administrative complexity of setting fees to numerous farmers precisely linked to the damages caused by their effluent is mind-boggling. No successful example of this type of taxation is presented in the literature.

Finally, outright purchases of water rights and/or land use rights provides another approach. For instance, acquiring rights to part or all of the polluting lands and managing it to assure water quality. Purchase of tropical forest lands by either public or private agencies has been undertaken to preserve first-growth forests, with water quality improvements as a side-benefit. Again, costs are borne primarily by beneficiaries, rather than by the land users whose practices are actually responsible for pollution.

Conclusions

Water's unique physical properties, complex economic characteristics, important cultural features, and essential role in supporting all life on earth distinguish it from all other natural resources. These multifaceted characteristics mean that developing effective water policies involves economic, ecological, environmental, legal, and political considerations. In most societies, political considerations dominate water use decisions. Nonetheless, most water policy options are framed and discussed in economic terms.

Water resources have moved to the forefront of international and national policy debates about how to reform policies to meet sustainability objectives. But, society's shifting and sometimes conflicting expectations crea difficult policy challenges related to the use of water resources. Water's multiple benefits and services are valued differently by different people and change dramatically over time. These multiple benefits and changing roles are challenging traditional concepts and institutions. Today, economic growth and development strategies require policies that integrate water into national economies and balance economic and environmental needs among national, local and international interests.

Sustainable development depends on sustainable water use. This search for sustainable economic development require, in part, both economy-wide and sector specific policy reforms. Economy-wide policies to create a favourable macroeconomic environment and water sector institutions and incentive structures to encourage resource efficiency among competing needs. The implications are that the era of large direct an indirect subsidies must end; that the full cost principle must be recognised, and that innovative approaches to demand management are required to address the human causes of water problems including water quality, degradation and overexploitation.

Environmental economics is contributing to this policymaking process as economists have responded to the most recent wave of sustainable development concerns by adapting and expanding the neoclassical framework in ways that provide a compelling view and a practical basis for addressing water-related environmental concerns. This theoretical and empirical work suggests that, whenever possible, incentive-based, market approaches to social goals, including environmental protection, offer the best hope for efficient and sustainable use of water resources.

[1] For example, in January 1992, the UN System sponsored the "International Conference on Water and the Environment" (ICWE) in Dublin. The ICWE called for innovative approaches to the assessment, development and management of freshwater resources. In addition, the ICWE provided policy guidance for the "UN Conference on Environment and Development" (UNCED) in Rio de Janeiro in June 1992. UNCED highlighted the need for water sector reforms throughout the world. In 1993, the World Bank issued a comprehensive policy paper defining its new objectives for the water sector. FAO recently established an International Action Programme on Water and Sustainable Agricultural Development. Likewise, UNDP, WHO, UNICEF, WMO, UNESCO and UNEP the regional development banks have developed water sect r strategies papers. The 1990 Montreal meeting, "NGOs Working Together," focused attention on drinking water supply and sanitation. The Canadian International Development Agency, the French Ministry of Cooperation, the German Agency of Technical Cooperation, the Overseas Development Administration (UK) and the U.S. Agency for International Development recently have developed water resources strategies for foreign assistance.

[2] In this context, resource economics uses population ecology to describe the natural environment and environmental processes are exogenous. Environmental economics uses ecosystem ecology, focusing on the various function that are performed by ecosystems.(Dasgupta and Maler, 1995)

[3] Health officials identify five categories of disease related to water: (1) water-borne diseases (typhoid, cholera, dysentery, gastroenteritis and infectious hepatitis); (2) water-washed infections of the skin and eyes (trachoma, scabies, yaws, leprosy, conjunctivitis and ulcers); (3) water-based diseases (schistosomiasis and guinea-worm); (4) diseases from water-related insect vectors such as mosquitoes and blackflies; and (5) infections that are caused by defective sanitation (hook worm).

[4] This section draws on Stringer, Young and Carruthers, 1993.

[5] Non-rival goods require large amounts of resources to exclude unentitled consumers from using the good. And exclusion costs are frequently very high for water services such as flood control and navigation systems. Goods and services that are non-rival in consumption are normally better-suited to public sector interventions, including ownership, provision and regulation.

[6] Charles Wolf and others have catalogued in considerable detail the advantages and disadvantages of government hierarchies for allocation of resources (see Cullis and Jones, 1987).

[7] See Gandhi (1995) for examples.

[8] See Cropper and Oats (1992) for a survey of recent theoretical and applied techniques in environmental valuation.

[9] The three main choices are: (1) market valuation of physical effects--dose response, damage functions, production functions and replacement costs; (2) stated preference-- contingent valuation method, and (3) revealed preferences--travel costs, avertive behaviour and hedonic pricing. The choice of technique depends on the type of environmental impact, the availability of information and the time and money available for evaluation.

[10] This user-focused approach involves managing people through organizations and institutions. Voluntary associations, government bureaucracies and private businesses are examples of organizations that operate on both the demand (user) side and the supply (delivery) side of water

References

Anderson G. and R.C. Bishop. 1985. "The valuation problem." In D.W. Bromley, ed., *Natural resource economics*. Boston: Kluwer-Nijhoff Publishing.

Anderson, K. and R. Blackhurst (eds.) 1992. *The greening of world trade issues*, Hemel Hempstead: Harvester Wheatsheaf.

Bhatia, R. and M. Falkenmark. 1992. *Water resource policies and the urban poor: Innovative approaches and policy imperatives*. Background paper for the International Conference on Water and Development. Dublin, Ireland.

Bohm P. and C.F. Russell. 1985. "Comparative analysis of policy instruments." In A.V. Kneese and J.L. Sweeney eds., *Handbook of natural resource and energy economics*, vol. 1, Elsevier Science Publishers: Amsterdam.

Boulding, K.E. 1980. "The implications of improved water allocation policy." In M. Duncan, ed., *Western water resources: Coming problems and policy alternatives*. Boulder, Co., Westview Press.

Bromley, D.W. 1989. *Economic interests and institutions: the conceptual foundations of public policy*. Basil Blackwell Inc.: New York, NY.

Bromley, D.W., D.C. Taylor, and D.E. Parker. 1980. "Water reform and economic development: institutional aspects of water management in the developing countries." *Economic Development and Cultural Change*, Vol. 28 No. 2.

R. Coase. 1971. "The theory of public utility pricing and its applications," *Bell Journal of Economics*, 1: 113-128.

Colby, M.E. 1990. *Environmental management in development*. World Bank Discussion Paper No. 80, Washington, D.C.: World Bank.

Dales, J.H. 1968. *Pollution, property and prices*. Toronto: University of Toronto Press.

Daley, H. 1990. "Towards some operational principles of sustainable development," *Ecological Economics*, 2.

Dasgupta P. and K. Maler. 1995. "Poverty, institutions and the environmental resource base." In J. Behrman and T.N. Srinivasan eds., *Handbook of Development Economics Vol IIIB*. Amsterdam: Elsevier Science B.V.

Gandhi, V.P. (ed.) 1996. *Macroeconomics and the environment*. Washington, D.C.: IMF.

David Getches. 1990. *Water law in a nutshell*, 2nd Ed., St. Paul, MN.: West Publishing.

Girma, M. 1992. "Macropolicy and the environment: a framework for analysis," *World Development*, Vol.20, No. 4, pp 531-40.

Gleick, P. 1993. Water in crisis. New York: Oxford University Press.

Goldin, I. and L.A. Winters (eds.) *The economics of sustainable development*, Cambridge: Press Syndicate of the University of Cambridge. Press

Guevara, M. I. P. 1995. *Trade, sustainable development, and the environment: a bibliography*, Ottawa: Centre for Trade Policy and Law.

Harrington, W., A.J. Krupnick and H.M. Peskin. 1985. "Policies for nonpoint-source pollution control," *Journal of soil and water conservation*, 40: 27-33.

supply systems. On the supply side, large hierarchical, bureaucratic systems usually control the capture, storage, conveyance and distribution of surface water. Demand side organizations such as water user associations are established, for example, to represent the interests of irrigators, to introduce and enforce water allocation rules or to maintain drainage ditches.

[11] Institutions are "...sets of ordered relationships among people which define their rights, exposure to rights of others, privileges and responsibilities" (Schmid, 1972). In this context, institutions set the "rules of the game" within which the economic system operates. For example, since the property rights system determines access to water, it is considered a water institution.

[12] For a discussion see, D.A. Stone, 1988 and Maass and Anderson 1978

[13] Most of these criticisms can be dealt with by a multipart pricing system: the first part sets marginal price equal to marginal cost; and the second part levies an assessment to recover those costs above marginal costs. Even so, multipart schedules often fail to correctly reflect the economic concept of opportunity costs, focusing instead on recovering historical or embedded costs. The opportunity costs that are relevant include both the cost of securing incremental supplies of water and the value of water in alternative uses.

[14] While Chile is the only country to establish a formal trading system for water rights, Rosegrant and Binswanger document the expansion in surface water and groudwater markets. Pakistan, for example is reported to hae actie market in 70 percent of its watercourses.

[15] For further discussion see Chapter 2 of Pearce and Turner (1990).

Hirschman, A.O. 1967. *Development projects observed.* Washington, D.C.: The Brookings Institute.

Homer-Dixon, T.F., J.H. Boutwell and G. W. Rathjens. 1993. "Environmental change and violent conflict," F.. *Scientific American* February, 1993

Hotelling, H. 1931. "The economics of exhaustible resources," *Journal of Political Economy*, April, 39(2), pp 137-75

ICWE. 1992. *The Dublin statement and report of the conference.* International Conference on Water and the Environment. 26-31 January. Dublin, Ireland

Kneese, A.V. 1962. *Water pollution economic aspects and research needs.* Washington, D.C. Resources for the Future.

Kneese, A.V. and B.T. Bower. 1968. *Managing water quality economics, technology, institutions.* Baltimore. The Johns Hopkins Press for Resources for the Future.

Libsey, R B. and K. Lancaster. 1956. "the general theory of second best." Review of economic studies, 24 11-32

Low, P (ed.) 1992. *International trade and the environment*, World Bank Discussion paper, 159 Washington, D.C.: World Bank.

Maass, A. and R.L. Anderson. 1978. "... *and the desert shall rejoice conflict, growth and justice in arid environments.* Cambridge, MA.:MIT University Press.

Munasinghe, M. and W. Cruz. 1995. *Economywide policies and the environment lessons from experience*, World Bank Environment Paper Number 10, Washington, D.C.:World Bank

Mink, S. 1993. "Poverty, Population and the Environment." *World Bank Discussion Papers* 189. Washington, D.C.: World Bank.

Norgaard, R.B. 1988. "Sustainable development: a co-evolutionary view," *Futures*, 20:6; 606-620

OECD. 1995. *The economic appraisal of environmental projects and policies: a practical guide.* Paris: OECD.

Panayotou T. 1993. *Green markets: the economics of sustainable development.* International Center for Economic Growth, San Francisco: ICS Press.

Panayotou, T. and K. Hupe. 1995. *Environmental impacts of structural adjustment programs*, Cambridge: Havard Institute for International Development.

Pearce, D. and Turner, R. 1990. *Economics of natural resources and the environment*, Hemel Hempstead: Harvester Wheatsheaf.

Postel, S. 1992. *Last oasis: facing water scarcity.* W.W. Norton & Company. New York.

Alan Randall. 1981. Property entitlements and pricing policies for a maturing water economy, *Australian Journal of Agricultural Economics* 25, 195-212.

Repetto R. 1986. *Skimming the water: Rent-seeking and the performance of public irrigation systems.* Research Report No. 4, Washington, D.C.: World Resources Institute.

Rogers, P. 1992. *Comprehensive water resources management: a concept paper.* Policy Research Working Paper Series, World Bank, Washington, DC.: World Bank.

Rosegrant, M. 1993. *Water markets, agricultural productivity, environmental Sustainability and consumer welfare. a three sector model.* Washington, D.C.: IFPRI.

Rosegrant, M. and H.P. Binswanger. 1993. *Markets in tradable water rights:potential for efficiency gains in developing-country agriculture.* Washington D.C.: IFPRI.

Runge, C.F. 1987. "Induced agricultural innovation and environmental quality: the case of groundwater regulation," *Land economics*, Vol.63, No.3, August, pp 249-258.

Ruttan, V.W. 1978. "Induced institutional change." In H. Binswanger and V.W. Ruttan, eds., *Induced innovation*, Baltimore, Johns Hopkins University Press.

Saliba, B., D. Bush, W. Martin, and T. Brown. 1987. "Do water market prices appropriately measure water values?" *Natural Resources Journal*, Vol. 27. Summer.

Schmid, A.A. 1972. "Analytical institutional economics: challenging problems in the economics of resources for a new environment." *American Journal of Agricultural Economics* 54, 893-901.

Segerson, K. 1990. "Incentive policies," In J.B. Braden and S.B. Lovejoy, eds. *Agriculture and water quality: international perspectives.* Boulder, CO. and London, Lynne Reiner Publishers

Solow, R. 1992. "An almost practical step toward sustainablity," Resources for the Future invited lecture, October 8, 1992. Washington, D.C.: Resources for the Future.

Stone, D.A. 1988. *Policy paradox and political reason.* Glenview, IL: Scott, Foresman and Co.

Stringer, R., R. A. Young, and I. Carruthers. 1993. "Water policies and agriculture," In, *The state of food and agriculture*, 1993, Rome:FAO.

UNCED. 1992. *Agenda 21*, See "The protection of the quality and supply of freshwater," Chapter 18, United Nations Conference on Environment and Development.

UNEP. 1991. *Freshwater pollution.* UNEP/GEMS Environmental Library. Nairobi: UNEP.

Wade, R. 1982. "The system of administrative and political corruption: land irrigation in south India." *Journal of Development Studies*, 18:287-299.

Yevjevich, V. 1992. *Water international* 17, No. 4, 163-171.

Young, M. D. 1992. *Sustainable investment and resource use: equity, environmental integrity and economic efficiency.* Paris: UNESCO.

Young, M.D. and B. McCay. 1995. "Building equity, stewardship, and resilience into market-based property rights systems." In S. Hanna and M. Munasinghe (eds.) *Property rights and the environment.* Washington D.C.: World Bank.

Young, R.A and R.H. Haveman. 1985. "Economics of water resources: a survey." In A.V. Kneese and J.L. Sweeney eds. *Handbook of natural resources and energy economics*, vol. II, Elsevier Science Publishers: Amsterdam.

Weinberg, M. and C. L. Kling. 1996. "Uncoordinated agricultural and environmental policy making: an application to irrigated agriculture in the west," American Journal of Agricultural Economics, Vol. 78, No. 1, February, pp; 65-78.

World Bank, 1992. "Development and the Environment," *World Development Report* 1992, Washington, D.C.: World Bank.