

Summaries

Policy issues and institutional impediments in the management of groundwater: lessons from case studies

CHARLES W. HOWE

The paper first identifies the several types of groundwater systems: those that are closely linked with surface water bodies; those subject to recharge from rainfall; and those having no significant recharge. The groundwater storage areas (aquifers) provide natural storage reservoirs with little evaporative loss. They provide natural transmission of water from the various sources to points of use. During periods of drought they provide reliable supplies. In some situations, groundwater quality is superior to that of surface supplies. Thus the coordinated management of groundwater and surface water supplies can yield substantial benefits.

Management and legal problems related to groundwater systems include failure to take advantage of surface water–groundwater linkages; overly rapid depletion of groundwater supplies with negative impacts on future economic activity; problems of aquifer compaction and related surface subsidence; poorly defined property rights in groundwater; and fragmentation of decision making among surface water, groundwater, and water quality agencies, each with different missions, responsibilities, and expertise.

Various policy instruments have been successfully used to ameliorate the problems facing groundwater management: regulations on well spacing, well capacities, and land surface per well to restrain extraction rates and the negative interactions among pumpers; limits on the number and capacities of pumps allowed; schemes for compensating surface water users whose water is taken by groundwater pumping; placement of a tax or fee on water pumped to reflect contemporary and intertemporal externalities; and tradable groundwater permit systems. The brief case studies in the paper illustrate the use of some of these instruments in solving groundwater management problems.

Irrigation water demand for the decision maker

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This paper aims at proposing a methodology to estimate irrigation water demand. Our approach is based on the evaluation of the farmer's value for water. Since markets for water do not exist in France it is not simple to determine this value. We define it as the maximum amount of money the farmer would be willing to pay for the use of the resource. Another specificity of our approach concerns the production function, linking the water to the yield, which is used in the estimation. Here, we do not specify that function and use a crop-growth simulation model, which give precise results concerning water–yield relations.

The procedure we propose is a two-stage method composed of a model of farmer behavior description and an optimization of the water repartition over the season, followed by an estimation procedure, the latter being chosen to be non-parametric, that is very flexible and allowing precise drawing of functions. First, we describe the farmer's program. He has to allocate a limited water supply during an irrigation season and maximize his profit evaluated at the harvest. We propose a numerical method for obtaining solutions to this problem based on an optimization algorithm. This algorithm integrates the agronomic model, EPIC-PHASE, an economic model, and an algorithm of search of the optimum. This numerical procedure is used for different weather conditions, and for several total water quantities available for irrigation. It generates a database composed of levels of total available quantity of water and the associated maximized profits. Second, using this database and non-parametric methods, we estimate and draw the maximized profit functions linking the total quantities of water available for a season to the profit made if this quantity was used optimally. The irrigation water demand functions, giving the price the farmers are ready to pay for having an additional unit of water are also estimated and drawn by a non-parametric derivation procedure.

This methodology is applied to estimate water irrigation demand in the south-west of France. Our results show that the irrigation water demand functions are decreasing, non-linear, and strongly depend on weather conditions. These functions can be decomposed into several areas. Irrigation water demand is inelastic for a small available quantity of water, for small quantities of water the farmer will still be ready to consume almost the same quantity of water, even if one increases greatly the price of the water. Then, as the quantities available increase the demand becomes more elastic, and the farmer is more reactive to a change in price, he will reduce consumption if the price is raised. The price levels at which the changes in

responsiveness to prices appear depend on climates and vary around 0.30 F/m³ for wet weather conditions up to roughly 1.60 F/m³ for a dry year. This information is a decisive contribution for defining water pricing policies and water savings when water scarcity becomes a leading issue.

Household demand and welfare: implications of water pricing in Cyprus

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This paper estimates household water demand in Cyprus. As in most European countries and the United States, water utilities in Cyprus choose among three types of pricing scheme, uniform, decreasing and increasing block rates, in their attempt to use the price of water as a management tool to influence its use. The government-controlled part of Cyprus is divided into 37 water authorities, each having its own tariff structure. The adoption of an increasing block tariff structure and differences in the application of this pricing policy across water authorities give rise to substantial water price heterogeneity in the island. Section 2 of the paper provides a detailed graphical and descriptive statistical analysis of the structure and distribution of water tariffs in Cyprus, between regions and income groups.

Economists have attempted to shed some light on the consequences of the choice of the pricing structure by paying attention to demand estimation. However, opinions concerning the appropriate methodology for estimating water demand models differ. Estimation under a block pricing structure requires appropriate modeling to account for the choice of both within and between block consumption. Earlier studies of water demand ignore the peculiar features of the presence of block rates and perform empirical estimation using ex-post calculated average prices. More recently, investigators combine marginal price and the so-called Nordin's difference variable (in the case of multiple tariffs, this variable is the difference between the total bill and what the users would have paid if all units were charged at the marginal price) in empirical models of residential demand. Section 1 of the paper reviews this literature.

In this paper we follow a different approach to modeling residential demand for water. The estimated model is derived in section 2 from a theoretical framework consistent with fundamental principles of the economic theory of consumer behavior (such as adding-up, price homogeneity, and symmetry). The choice of the Quadratic Almost Ideal

Demand System (QUAIDS) model reflects the fact that it belongs to the family of rank-3 demand systems, the most general empirical representation of consumer preferences that satisfies integrability. We use a rank-3 demand system for two reasons. First, we shall estimate demand for water using individual household data for which lower rank demand systems are too inadequate to capture the nonlinear income effects pertaining to these data. Second, we need a demand system that satisfies integrability (the ability to recover the parameters of the indirect utility function from empirical demand analysis) because we plan to analyze the welfare implications of alternative water pricing policies on empirical grounds. We consider the ability to evaluate the welfare implications of alternative water pricing policies particularly important, given the significance attached to equity and the strong political objections to water price reform based on political economy arguments. Section 3 of the paper models tariff effects on consumer demand and welfare through a QUAIDS.

The theoretical model described above is applied to individual household data, contained in the Family Expenditure Survey (FES) of Cyprus 1996/97. This allows estimation of the price and income elasticities of residential demand for water in Cyprus and evaluates the welfare effects associated with changes in the water pricing system. In section 4, which contains the empirical contribution of the paper, we find that the current water pricing system is progressive but inefficient in the sense that it introduces a substantial price heterogeneity that cannot be justified on the basis of efficiency or equity criteria. It cannot be justified on efficiency grounds because it is difficult to imagine that in a small island like Cyprus such large regional differences in price can reflect difference in supply costs. The regional price heterogeneity cannot also be justified on equity grounds because we found users consuming much smaller amounts of water.

Moreover, the empirical analysis suggest that the price elasticity of demand for water ranges between -0.4 for households in the lowest and -0.8 for households in the highest 10 per cent of the income distribution. This means that, in the case of residential water use, price can play a role in the context of a demand management scheme designed to tackle the growing fresh water problems in Cyprus. Such an approach, however, should take into account the distributional impact of alternative price regimes. Any major water price reform is bound to have effects on the welfare of individual consumers. In other words there will be winners and losers, and therefore there will also be a need to consider how to deal with potential hardship caused by the water price reform.

Can public sector reforms improve the efficiency of public water utilities?

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The inefficiency of public water and sewerage companies is a major problem in many developing countries, leading to environmental degradation and health problems in rapidly growing urban centers. Privatization of public water utilities is frequently viewed as a solution to this problem under the assumption that the private operator will be more efficient than the public one.

However, the present study points out that the observed inefficiency in the water sector is likely not to depend on the type of ownership, but rather on the monopolistic structure of the water sector and on the information asymmetry between the operators and the users. It is argued that any operator, public or private, will be tempted to benefit from the lack of competitive pressures and from the lack of control by being inefficient.

The question raised by this study is whether public sector reforms, like the decentralization of water services and the establishment of an autonomous regulator, could improve the efficiency of public water companies. In theory, decentralization might make the managers of the water company more accountable by moving them closer to the consumers. In addition, the establishment of an autonomous regulator could provide a control mechanism of the performance of the different operators.

To answer the above question we examine the reforms of the Mexican water sector of 1989. These reforms consisted in decentralizing the responsibility for water supply from the state to the municipal level and in creating a separate regulatory framework. A sample of 110 water and sewerage companies for the year 1995 is analyzed to establish whether the reforms had any significant effect on the efficiency of the public operators. To measure the relative efficiency of the water companies Data Envelopment Analysis was used.

The finding of the study is that none of the reforms implemented in Mexico had a significant effect on the operational efficiency of the public water utilities. While the reforms might represent steps in the right direction, by themselves they appear to be insufficient, since they did not address the lack of competitive pressures and of comparative information in the water sector.

The policy conclusion of the study is that in order to improve the efficiency of public water operators it is necessary to introduce competition and transparency among the operators. Since real competition is excluded by the fact that it would be anti-economical to duplicate supply systems, it is proposed that virtual competition could be introduced through regulation. In order to overcome the information asymmetry, a regulator could

publish efficiency measures of the water companies and make the local users aware of the relative performance of their company. In order to introduce competitive pressures, the regulator could use the better-performing companies to set competitive price levels. It is suggested that the relative efficiency measures obtained from Data Envelopment Analysis are particularly adequate for competitive benchmarking.

Valuing indirect ecosystem services: the case of tropical watersheds

BROOKS KAISER and JAMES ROUMASSET

Environmental resources in developing countries are at risk from many factors besides the direct effects of development projects. Tropical forests, for example, may be degraded through population pressure, fire, and the propagation of alien species. These risks cannot be managed through *negative environmentalism* as epitomized by environmental impact requirements. Rather, active steps (*positive environmentalism*) are needed to conserve environmental resources and provide for sustainable development.

Positive environmentalism requires assessing the nature and causes of environmental degradation and designing appropriate policy reforms and conservation projects. In order to select among and prioritize the many possible conservation projects, benefit-cost analysis is recommended. Unlike most government projects, however, which may have some non-market spillovers, the benefits of conservation projects may be entirely non-market in nature. In such cases, basing the entire case for the conservation project on contingent valuation (survey) studies and questionable valuation techniques may meet with skepticism from both academic and political circles. Whenever possible, the ecological services of the environmental resources in question should be identified and evaluated in the context of a structural model of the ultimate benefits of those services.

The example chosen for the present study involves the groundwater-recharging services of a forested watershed on the Island of Oahu, Hawaii. A conservation project helps to prevent the degradation of the forest cover and the quantity of recharge. These benefits can be evaluated according to the water they save. As in most developing countries, however, water in Hawaii is priced by a public agency and subject to political forces. Accordingly, water has some of the attributes of a non-market good. At best, the current price charged for water services is a lower bound of the

efficiency price. Even then, the price that will be charged in the future is highly uncertain.

This brings the analyst to a conceptual crossroads. Ordinarily, project benefits are evaluated according to the consumer surplus that they generate or according to the 'second-best shadow price', which in turn is a weighted average of the supply price and the demand price. The reference point for both methods is the status quo (distorted) equilibrium price. But while the status quo price is observable for the current period, the future price depends on future policy decisions and is unknown. Since the value of recharge water depends on the present value of the aquifer, which depends in turn on future policy decisions, neither the consumer surplus nor the second-best shadow price method is appropriate.

Accordingly, we base the estimation on first-best (efficiency) prices. This method requires the analyst to calculate optimal management for the recharge profiles with and without the conservation project. The optimization yields efficiency prices for each period, which in turn are used to evaluate the optimal groundwater extraction for that period. The difference in the corresponding present values of the two scenarios is the value of the conservation project. A further advantage of the first-best method is that it is directly comparable with the methods inherent in national income accounts. Because the value of an economy's environmental resources may be quite large, it is tempting to compare that value with a country's net national product (NNP). Since the conceptual foundation of NNP is first-best prices (Weitzman and Löfgren, 1997), comparing the consumer surplus of environmental resources with NNP (for example as in Costanza *et al.*, 1997) would be inappropriate and could easily involve overestimation of the former value.

In our example, a proposed conservation project in the Ko'olau watershed on Oahu, avoids degradation of both the quality and quantity of the forested area, thus avoiding the decrease in recharge that would otherwise occur. Using the method just described, the value of the increased recharge provided by conservation is estimated at between 1.4 and 2.6 billion dollars, depending on the social discount rate applied to intergenerational benefits. Such benefits, quantified even without attempting to assign values to forest amenities such as endangered species or aesthetic and recreational benefits, justify significant expenditures on the maintenance of the natural capital.

The analysis in this paper may be of interest to policy makers who wish to couch arguments for conservation activities in terms of quantifiable, direct economic benefits. The method and illustration may also be used to demonstrate the benefits of improving income accounting procedures in order to incorporate returns and possible depreciation of natural capital. Properly extended, full national income accounts can thus become the centerpiece of economic planning for sustainable development.

Solving water pollution problems along the US–Mexico border

LINDA FERNANDEZ

The paper investigates the potential for solving wastewater pollution problems along the US–Mexico border. By including trade policy changes and the presence of a formal institution that could foster cooperative decision making over pollution control, the paper offers a comparison of outcomes with two different trade policy scenarios along with a comparison between with and without the institution making pollution control decisions. With data from one watershed, it is possible to derive numerical characterizations of the effects on pollution and employment under the different scenarios. With statistical analysis, it is possible to characterize the trend of decision making on the part of the institution making decisions to solve water pollution problems along the border.

Transaction costs and trading behavior in an immature water market

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In many places throughout the world, water is a limiting factor on development. In arid regions, the amount of precipitation and usable groundwater may be small, particularly when compared to crop water requirements in agriculture. Further, most countries are experiencing population growth, particularly in cities, adding to the pressures on water systems. In such environments, it is essential to make the most of available water supplies and, again, economists and others have called for allocation by price (see, for example, the recent book by Easter *et al.*, 1998).

While a number of local water markets are active throughout the world, broader inter-sector water markets, in which long-term water rights are actually bought and sold, have been slower to develop (Easter *et al.*, 1998). Unlike markets for most commodities, most water markets have no centralized trading locations and no publicly posted market prices. Due to the lack of public and private institutions supporting water markets, potential

traders often spend considerable resources gathering market information, finding potential trading partners, negotiating deals, and legally effecting transfers, that is, trading in water markets is subject to large transaction costs.

This paper develops a theoretical model to examine the effect of transaction costs on water markets. The model is applied to a case study from the United States. While the United States is undoubtedly a developed country, its water market institutions are only in their adolescence and are thus of interest to many countries.

Our analysis of the emerging water market draws on the transaction cost economics literature originated by Williamson. The relevant transaction costs include both the *ex-ante* costs of drafting, negotiating, and safeguarding an agreement, and the *ex-post* costs associated with contractual breakdowns and rent seeking behavior. Our research centers on the influence of transaction costs on patterns of trade in informal water markets.

The water market we study in this paper is the one occurring among farmers in Westlands Water District in California's Central Valley, the main agricultural region of the state. Westlands is the largest water district in California, covering nearly 600,000 acres and including approximately 800 farms.¹ Every year, farmers in Westlands complete thousands of water trades involving hundreds of thousands of acre-feet.² Many of these farms within Westlands are affiliated, often by kinship and sometimes by other economic relationships, and are effectively under common management. We term a group of affiliated farms a *network*. By grouping farms into networks, it is possible to distinguish between 'internal trades' within networks and 'market trades' between unrelated farms.

Examination of the trading data provides ample evidence of transaction costs. Although trading is active in Westlands' water market, roughly two-thirds of the trades in terms of both number and volume occurred *within* networks. The prevalence of internal trades provides the most obvious support for the hypothesis that there are high transaction costs associated with market trades.

The theoretical model of trading and transaction costs also points out the informational and competitive advantages enjoyed by large networks in informal markets. Thus, these entities may oppose the development of more formalized mechanisms of exchange in which all participants are on the same footing. Despite the advantages of large networks, the relatively high market participation rates among small networks indicate that the water market also provides small networks with significant benefits.

Further evidence of the role of transaction costs is provided by the prevalence of repeat trades. That is, networks that made market trades often dealt repeatedly with the same networks. This behavior, analyzed in the papers by Carlton (1991) and Kranton (1996), is another indication of high transaction costs. By developing long-term trading relationships,

¹ A water district is essentially a local utility that receives water from a government water project and delivers it to its members, each of whom have a fixed entitlement to water per unit of land.

² An acre-foot equals 326,000 gallons of water.

farms may be able to reduce the transaction costs associated with future trades.

This paper furthers our understanding of the impacts of transaction costs on trading patterns in informal markets, both theoretically and in the specific context of water markets. It provides valuable information for policy makers who are evaluating strategies to promote water markets in regions throughout the world. Most importantly, it demonstrates the economic value of institutional reforms and information technologies that reduce market transaction costs.

Environmental improvement with economic development through public information provision

DANIEL EDWARD OSGOOD

Although there is a global effort in the government provision of farm relevant weather information, this effort is facing considerable criticism. It is argued that the government should not provide weather information to farmers, considering the possibility of privatization of information systems, and the use of alternative policy options such as taxes, markets, and fees.

This paper demonstrates that there is a fundamental economic justification for the use of public weather information systems if the following two conditions hold: 1. Agricultural production systems rely on weather information, and 2. the information is non-excludable and non-rival (the weather information can be easily pirated). This paper shows that when these conditions hold, there are market failures that prevent the private sector from optimal behavior. Due to these market failures, there is a government role in the provision of weather information. In some cases, the pirating that reduces the private provision of weather information can be taken advantage of by the policy maker to broaden program impacts.

The paper discusses how other policy tools, such as taxes and fees, can be difficult to implement and can reduce the economic viability of agriculture. It compares and contrasts the applicability of weather information systems and price incentive for industrialized agriculture in California and in the developing country context of Mexico. In both cases, the paper discusses how, under the correct conditions, public provision of weather information can reduce wasted water, increase agricultural output, and improve the viability of farms, providing a tool that simultaneously addresses concerns about the environment and economic development.

Aspects of water markets for developing countries: experiences from Australia, Chile, and the US

HENNING BJORN LUND and JENNIFER MCKAY

Water market reforms are being promoted by international organizations, such as the World Bank, and pursued within many developing countries. Actual experiences with water markets are limited and the opinions regarding the beneficial or detrimental impacts diverse. It is therefore crucial to learn from the few functioning markets. Some of the longest operating, and most mature markets in the world, are to be found in south-eastern Australia. This paper examines the outcome of water trade in southeastern Australia and combined with US and Chilean experiences outlines some lessons for the introduction of markets in developing countries.

Policy makers place considerable expectations on economic instruments such as water markets, privatization and full cost recovery prices. Academics, and among them foremost economists, have predicted considerable gains from trade. These are founded on the belief that:

- Tradable water rights give water a value separate from land, and provide an incentive to use water more efficiently, since water saved can be used to increase production or sold.
- Full cost recovery prices will facilitate this process, by encouraging or forcing inefficient irrigators on degraded soils, as well as low value users, to sell their water, since they will not be able to sustain farming. High value producing irrigators, with efficient water use on suitable soils will purchase the water. This will result in increased output from the water and thereby improve the financial position of the irrigator as well as the local community. This solution is also perceived to be socially equitable, since the buyers should be able and willing to fully compensate the sellers in the process leaving both parties better off.
- Reallocation by market forces reduces government costs, by limiting demand for new supply, while privatization and full cost recovery prices reduce government responsibilities for maintenance of infrastructure.

This paper indicates that there are many benefits to be gained from water markets in developing countries, and many lessons to be learned from existing and emerging markets. However, it is increasingly accepted that pure economic and market-based approaches are falling short of social and non-economic aspirations in many developing countries. Markets therefore need to be adapted to the social fabric and environmental constraints

of the local area and have to take into account the legacy of past policies. The lessons for existing markets clearly indicate that successful formal markets require complex institutional and legal structures, as well as strong social and economic capacities. Many developing countries, especially low-income developing countries, lack these structures and capacities. Formal water markets are therefore unlikely to be successfully implemented, while their implementation in better established developing countries are likely to be postponed, until resource conflicts are so severe as to force the hands of governments. There is a clear role to play here for development aid organizations to assist in setting up the institutional and legal frameworks required. While this takes place, informal water markets, such as those discussed in India and Pakistan, can play an important role in facilitating a more equitable access to water resources.