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14. Cost–benefit analysis and efficient water allocation in Cyprus

B. Groom, P. Koundouri and T. Swanson

1. INTRODUCTION

The scarcity of water resources in both arid and temperate countries alike is one of the most pervasive natural resource allocation problems facing water users and policy-makers. In arid countries this problem is faced each day in the myriad of conflicts that surround its use. Water scarcity is a fact with which all countries have to become increasingly involved.

Water scarcity occurs across many dimensions. First, there is growing demand for water in residential, industrial and agricultural sectors stemming largely from population and economic growth. Secondly, supply-side augmentation options have become increasingly constrained and restrictively costly in many countries. In combination, demand growth and supply-side interventions have stretched current water availability to its hydrological limits. In addition to these quantity constraints, the limits to the assimilative capacity of water resources for human and industrial waste have been reached in many places, and the quality of freshwater has been degraded (Winpenny, 1994).

In turn, water scarcity has become an important constraint on economic development, which has resulted in fierce competition for scarce water resources between economic sectors that rely upon it (Winpenny, 1994; World Bank/EIB, 1990). Water scarcity is important for sustainability in economic development as well, on account of the many associated environmental/watershed services. In the face of hydrological constraints, the focus of current thinking in water resource management is on the allocation of scarce water between competing demands (Dublin Conference, 1992; UKWIR, 1999; Winpenny, 1994).

How is it possible to allocate water between its many competing uses, all of which depend on water for their existence? Clearly, water resources are necessities for many of the most important goals of every society. First, water is a necessity for human existence. The absence of clean drinking water and sanitation leads to health problems, whilst the lack of access

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to/property rights for water resources per se is a significant dimension of poverty. Water is also an important input to economic activities and can be seen as both a production and consumption good (Young, 1996). Furthermore, water is a public good contributing to recreation, amenity and general environmental and watershed values as an input to ecosystems and habitats. How can it be possible to balance such crucially important, but competing uses?

The fact is that a balancing of these uses must be accomplished, and the mechanism for doing so must be carefully constructed. The existing overlay of complex hydrological, socio-economic and property rights/legal environments (in many if not most jurisdictions) predisposes water resources to open access appropriation within the watershed and the consequence of negative environmental and economic externalities (for example, the degradation of wetlands and coastal fisheries, depletion of aquifers and loss of watershed services). In short, the combination of the arbitrariness of the prevailing property rights structure for water resources in most jurisdictions and the failure of markets to capture the value of many watershed services necessarily imply that the prevailing distribution of water within most societies is not likely to be the most desirable one.

In what follows, a 'watershed economics approach' is proposed which is composed of two important stages. In the first stage, economic valuation techniques are used to establish the economic value of the competing demands for surface and groundwater, incorporating where necessary an analysis of water quality. The valuation exercise allows the balancing of demands based upon the equi-marginal principle to achieve economic efficiency. In the second stage, a policy impact analysis is proposed, which addresses issues of social equity and the value of water for environmental/ecological purposes. The analysis is undertaken within the confines of the watershed, the most natural unit for the analysis of water allocation and scarcity since it determines the hydrological links between competing users and thus the impacts of one user upon another. The methodology is encapsulated by a case study of the Kouris watershed in Cyprus.

The methodology described here and the case study which accompanies it provide an example of how CBA of water policy can be structured in the context of the watershed. They show how the multifarious constraints faced by watershed managers and policy-makers can be usefully evaluated and traded off using the principles of CBA and the important considerations of environment linkages and equity.

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2. METHODOLOGY

In this section we outline the methodology we propose for application to the underlying problem of watershed management. This methodology is based on (1) the identification of the appropriate unit for management; (2) the agreement of the objectives of water allocation; (3) the evaluation of the various attributes of water demand within that unit; (4) the identification of optimal water resource allocations relative to objectives; and (5) the assessment of the impacts of the proposed reallocation.

2.1 The Appropriate Management Unit

The watershed is a natural unit of analysis for addressing the balance of supply and demand for water, and the issues of efficiency, equity and sustainability, for a number of reasons. First, the aggregate availability of water resources, including sustainable yields is bounded by the hydrological cycle of the watershed. Second, the interaction between different water sources (for example, groundwater and surface water) is confined by the watershed. Third, the demands for water interact within the watershed and the hydrological impacts of one water user upon another and upon environment, that is, externalities, are defined by the watershed. For these reasons, an understanding of the hydrological cycle in the watershed area in question is a prerequisite for the determination of efficient, equitable and sustainable water resource allocation.

2.2 The Objectives of Water Allocation

Given the natural water resource constraints, there is a clear need to address the pattern and growth of water demands in order to address the imbalance. The methodology proposed provides the policy-maker and planner with a transparent approach to balancing the competing demands for water subject to the natural constraints. The approach is based on the comparison of the economic value of water in different sectors, in terms of quantity and quality, in comparable units of measurement. The overall objective of public policy is to maximize societal welfare from a given natural resource base subject to those valuations. The key objectives of public policy in the allocation of resources are as follows:

- *Efficiency*. Economic efficiency is defined as an organization of production and consumption such that all unambiguous possibilities for increasing economic well-being have been exhausted (Young, 1996).

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For water, this is achieved where the marginal social benefits of water use are equated to the marginal social cost of supply, or for a given source, where the marginal social benefits of water use are equated across users.

- *Equity*. Social welfare is likely to depend upon the fairness of distribution of resources and impacts across society, as well as economic efficiency. Equal access to water resources, the distribution of property rights, and the distribution of the costs and benefits of policy interventions are examples of equity considerations for water policy.
- *Environment and sustainability*. The sustainable use of water resources has become another important aspect in determining the desirable allocation of water from the perspective of society. Consideration of intergenerational equity and the critical nature of ecological services provided by water resources provide two rationales for considering sustainability. In addition, the *in situ* value and public good nature of water resources should enter into water allocation decisions.

2.3 The Evaluation of Water Demand

For physical, social and economic reasons, water is a classic non-marketed resource. Even as a direct consumption good, market prices for water are seldom available or, when observable, often are subject to biases such as subsidies, taxes and so on. Similarly, environmental and ecological water values are rarely explicitly marketed and priced. Thus the economic value of water resources is seldom observed directly. The balancing of demands to resolve the resource conflicts described above requires the identification and comparison of the benefits and costs of water resource development and allocation among alternative and competing uses. In addition, water management policies have widespread effects on the quantity and quality of water within a watershed and the timing and location of supplies for both in- and off-stream uses. In general, these impacts have an economic dimension, either positive or negative, which must be taken into account in policy formulation. Again, the value of these impacts is seldom observed directly.

Fortunately, economists have refined a number of techniques to value water resources and address the balance of demands and evaluate the impacts of water management policy. The first step towards the evaluation of economic benefits requires the identification of the demands for the resource. Water is needed for all economic and social activities, so the evaluator is faced with the problem of identifying a multi-sectoral demand curve. The dimensions of demand include municipal and industrial, agricultural, tourism and environmental (recreation, amenity and ecological).

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The valuation of each of the identified demands usually calls for a different approach for the following main reasons:

- the specific economic and hydrological context;
- data availability; and
- because the use of the resource is sector specific.

The residential and tourist sectors exploit the use value of water and use it as a consumption good. The agricultural sector derives use value from water as an input in production. The value of water related environmental goods can be a use value or a non-use value, including so-called existence value.

The valuation techniques allow the estimation of the following desirable parameters:

- *Marginal value of water*. The efficient balance of demands from a given source is found where the marginal value (benefit) of water is equated across users. In any given context, efficiency is achieved where the marginal value of water is equated to marginal social cost.
- *Price elasticity of demand (PED)*. This measures the responsiveness of demand to price changes. It characterizes the demand function and tells the policy-maker the extent to which prices must change to cause demand to fall to a particular (for example, efficient or sustainable) level.
- *Income elasticity of demand (IED)*. This measures the extent to which the demand for water varies with income. It tells the policy-maker whether water is a necessity or a luxury good and provides one way in which to assess the fairness of pricing policies. In combination with PED, IED can be used to estimate welfare changes resulting from policies.
- *Marginal or average willingness to pay for public goods (WTP)*. This estimates the strength of demand for water as an environmental good. This determines in part the efficient environmental allocation of water.
- *Marginal willingness to pay for quality changes of common access resources*. This parameter estimates the value of quality attributes of the resource, which are particularly important if the resource is used as a productive input.
- *Risk parameters*. Measurement of preferences towards risk and uncertainty. Useful for establishing policies, which reduce the impacts of risk on consumer groups occasioned by reason of variability in water availability.

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2.4 Balancing Water Demands in the Watershed

The outputs of the demand analysis allow the determination of the economically efficient allocations of water resources. The first element of an economically efficient allocation is the equi-marginal principle. This prescribes that each use of the water resource should achieve the same benefit from that water at the margin. In short, if water is more heavily valued at the margin in one sector than another, then it should be reallocated towards that sector until equality is achieved. The second element of the economically efficient allocation is that aggregate water resources are allocated efficiently where the marginal social benefit of their use is equated to the marginal social cost of supply.

One option for achieving an economically efficient water allocation is the use of the instrument of water pricing, where water is uniformly and universally charged at the marginal social cost of supply. This has the following implications. First, competing demands will each make use of the supply until its marginal benefit is equated with marginal social costs of supply (the equi-marginal principle). Note that this implies that every use must receive an equal marginal benefit from water resources in the optimum. The second implication is that aggregate demand for water will expand until the marginal benefit is equated with the marginal social cost of supply (aggregate efficiency). Demand is hence endogenous and managed within this model. The third implication is that the key to the success of the policy is the determination of the appropriate marginal social cost of supply and the marginal benefits to environmental uses.

2.5 Deriving Policies from the Methodologies – Policy Impact Analysis

There is a second phase to the water allocation methodology that follows from the consideration of the implementation of the conclusions from the first. The discussion here has largely been phrased in terms of the use of water pricing as the appropriate allocation mechanism, but this need not necessarily be the best or most appropriate instrument for allocating water in every context. There are many different approaches to enable the efficient allocation of water resources – pricing, marketable permits, even auctions (Dinar, 1996; Easter et al., 1999; Winpenny, 1994). Ultimately, the particular context must be considered for the feasibility of the various instruments, and the policy-maker must determine the most appropriate allocation mechanism within that context.

Secondly, it is crucial to note that an economically efficient allocation need not necessarily be an equitable or sustainable one. Additional analysis is required to assess the distributional impacts of the allocation recommended

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by the equi-marginal principle. The hydrological impacts of the allocation need to be assessed in order to assess whether the various demands are compatible within the existing watershed. Finally, the continued provision of basic environmental services within the watershed needs to be considered. In summary, the watershed needs to be double-checked for unforeseen externalities and for missing markets for watershed services to ensure that intra- and inter-temporal efficiency is achieved and that equity and sustainability considerations are properly considered.

The methodology can therefore be thought of as two complementary stages, the first stage to ascertain economically efficient water allocations and the second stage consisting of a policy impact analysis. The overall evaluation strategy, applied to the case study of the Kouris watershed in Cyprus, is shown in Figure 14.1.

3. CASE STUDY

The following study illustrates how the economic watershed appraisal methodology described above has been implemented in Cyprus. The Kouris watershed is used as an example of a watershed with multiple water use conflicts. The valuation process for the sector demands in Cyprus and the policy implications are described.

3.1 Water Supply in Cyprus

Cyprus is an arid island state situated in the north-eastern Mediterranean (Figure 14.2) in which renewable freshwater resources are highly constrained. The hydrological cycle of Cyprus is characterized by spatial and temporal scarcity in water quality and quantity. Eighty per cent of the rainfall is lost through evapo-transpiration, the remaining 20 per cent can be considered as the available annual water resources in Cyprus.

A number of different water supply investments and interventions have been made in Cyprus. In addition to surface water dams and groundwater exploitation, these included recycling, desalination and even evaporation suppression, cloud seeding and importation of water. The most significant investments have been those contributing to the Southern Conveyor Project (SCP). This scheme forms an interconnected water supply system, which allows the transfer of water resources throughout the southern part of the island and also to and from the capital, Nicosia. The scheme was designed to supply water to irrigated agriculture and residential areas, alleviating the spatial and temporal scarcity of water supplied in the country. The SCP effectively links all groundwater and surface water sources from the

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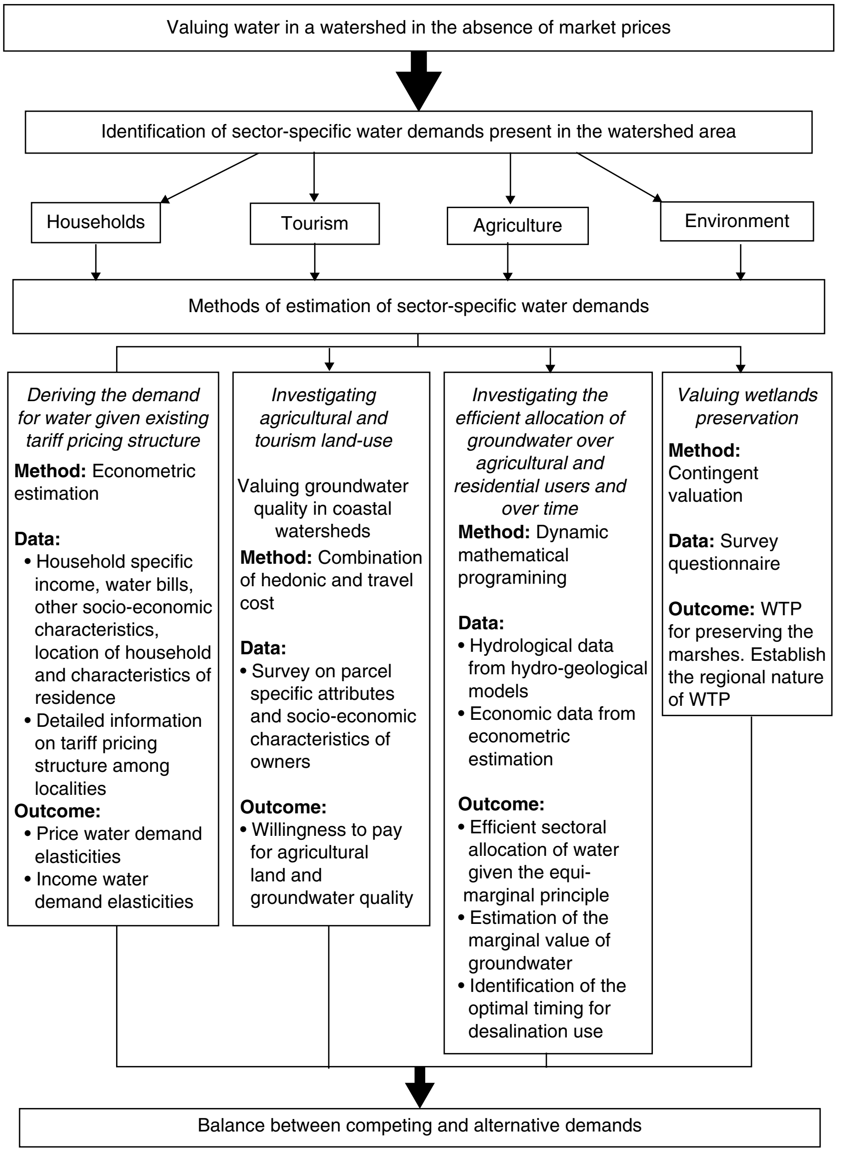

Figure 14.1 Overall evaluation strategy applied to the Kouris watershed in Cyprus

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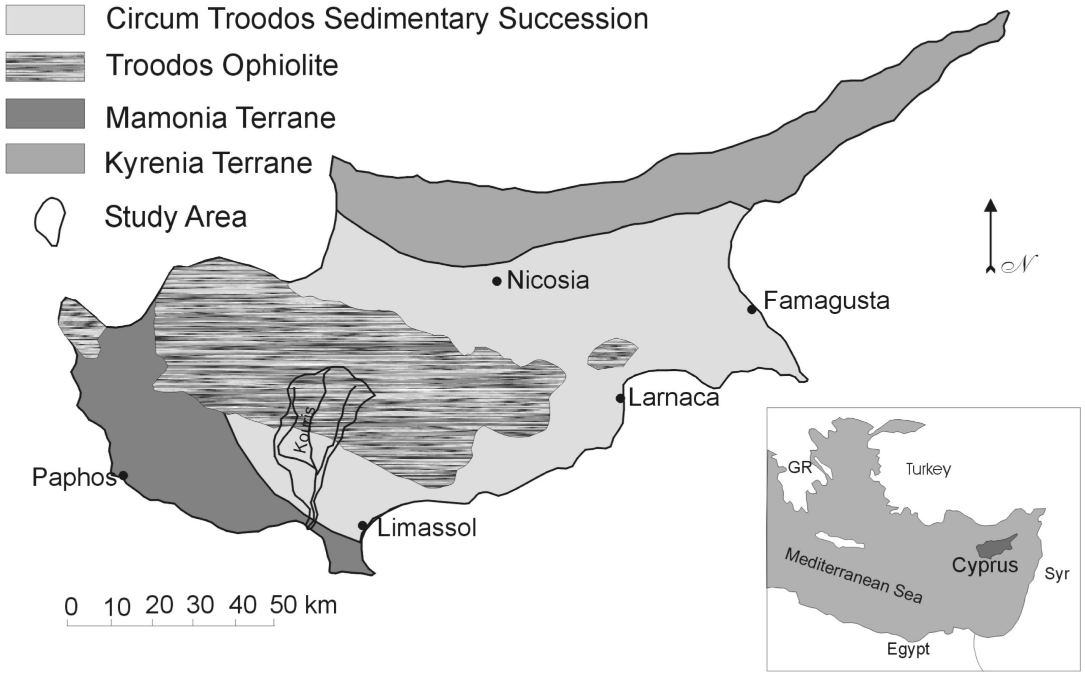

Source: Boronina et al. (2001).

Figure 14.2 The Kouris catchment in Cyprus

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Diarizos river (near Paphos) in the west to Paralimni (south of Famagusta) in the East. As a result, the management of the individual catchments in Cyprus has become of national importance and consequence (World Bank, 1996).

Currently all aquifers are exploited beyond their safe yield, with the excess of use over natural recharge estimated to be 40 million m^3/annum. The possibilities for additional exploitation of surface water have been largely exhausted and this has necessitated the consideration and/or use of costly unconventional sources such as desalination, recycling and evaporation suppression.

3.2 Water Demand in Cyprus

The sectoral demand for water is shown in Table 14.1 for the three major water schemes in Cyprus. It can be seen that approximately 75 per cent of current water use is in irrigated agriculture. The majority of the remaining demand involves urban areas, tourism and industrial demands.

There is a distinct seasonality to the demands for water from these water-consuming sectors. Urban demands are clearly higher in the tourist season, whilst the demands for agriculture also vary according to the growing season. Economic growth has averaged 6 per cent over the past 15 years, driven largely by the annual growth in the tourist sector (up to 10 per cent per year). There has also been economic growth in the industrial sector. Under current government plans, the irrigation sector will be expanded in the coming years, having grown at a rate of 2.2 per cent over the period 1980–92. Coupled with an expected population growth of 0.9 per cent per year and rapid urbanization, these will place further pressure on water resources in the years to come.

Table 14.1 Water consumption in the major water schemes in Cyprus (in millions m^3/annum in 1994)

Water scheme	Urban, industry and tourism	Irrigation	Total
Southern Conveyor System	42.7	45.9	88.6
Paphos System	4.2	23.2	27.5
Khrysokhou System	0.4	6.3	6.7
Other	8.1	84.5	92.6
Total	55.4	160.0	215.4

Source: adapted from World Bank (1996).

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Price is a significant determinant of water consumption. The consumption of water resources by irrigated agriculture is subsidised up to 70 per cent of the average unit production costs (World Bank, 1996). Current pricing strategies in urban areas differ significantly between municipalities, but generally involve substantial cost recovery.

3.3 Water Balance and Property Rights

Given the spatial and temporal variability of water resources and demands, the water balance varies from one watershed or water scheme to the next, and from one year to the other. The scarcity of water resources in Cyprus is thus characterized by extreme fluctuations over time and space of water supply and demand. Of the water schemes shown in Table 14.1, the SCP has the least favourable water balance (World Bank, 1996). The SCP caters for 40 per cent of the aggregate demand, 80 per cent of all urban demand and 25 per cent of all agricultural demand. It is the deficit of surface water flow, which causes the main shortfall. However, given the yearly fluctuations in precipitation and the resultant surface flow, the scarcity and the severity of the deficit varies from year to year.

The negative water balance is reflective of the interaction of supply and demand, and the underlying distribution of the right to control resources. Agriculture is clearly the largest water consumer. Table 14.1 shows that the major water schemes all have significant irrigation components, and indeed the primary motivation for the development of some of these projects was to maintain water supply for expansion of irrigation. The deficits in the water balance illustrate a conflict in resource management stemming from an absence of co-ordinated control of water use and the balancing of those demands with supply in a manner consistent with the underlying hydrology. The rights to water stem from government control. Non-governmental schemes consist of many scattered, small individual and communal schemes, like those using groundwater from the Kiti aquifer and the upper reaches of the Kouris catchment. The rights to groundwater resources are largely common property or open access here, despite the provisions of the 1946 Well law.

In addition to these water users, direct diversions from surface water flows, mainly in the Troodos mountains, including the Kouris catchment, for use by individuals and communal irrigators, account for 150 million m^3 per year of total resource availability. Surface water is also subject to open access, and farmers have the rights to construct irrigation schemes and use surface water (World Bank, 1996). Urban water resources are largely supplied by public schemes such as the SCP, but also by localized commissions from groundwater and surface water schemes.

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In summary, although the government has the responsibility for monitoring and protecting water resources, this responsibility is divided between many institutions, resulting in a fragmented regulatory framework (Grimeaud, 2001). A brief overview of the institutional and legislative background to water policy in Cyprus is given in the appendix to this chapter.

3.4 The Kouris Watershed

The current water balance in the SCP and the overdraft of groundwater resources are indicative conflicts between resource use and the natural constraints of water supply that have arisen under the current water management environment. The current extent of resource use is clearly unsustainable and there is nothing to guarantee that the benefits or social welfare derived from water resources are maximized or well distributed under the current pattern of water demand.

The conflict can be illustrated with the help of the Kouris watershed. The Kouris watershed covers 300 km^2 in the south-west of Cyprus (see Figure 14.2). The watershed contains storage dams with a total capacity of 180 million m^3 and provides much of the surface water for the SCP. The largest single storage dam is the Kouris Dam, with a capacity of 115 million m^3. The water users within the watershed are many and disparate and their property rights to water vary. In the upper reaches of the watershed, agricultural users extract groundwater and divert surface water for irrigation purposes under a common property arrangement. Downstream, water is diverted to storage dams for distribution to the main urban centres and to other irrigation schemes via the SCP. In the lower reaches of the watershed, surface water feeds into the coastal wetland areas, which provide a habitat for indigenous wildlife and migratory bird species.

It is widely believed that the uncontrolled growth of private and communal water use in the upper reaches of the Kouris watershed has contributed to reduced surface flows for the SCP (World Bank, 1996). Given the inter-basin transfers that the SCP allows, this watershed issue is of national consequence. Furthermore, the storage dams of the SCP have reduced the freshwater resources reaching the coast and feeding wetlands. There is concern that this has caused damage to the habitats important to migratory species. The management of water resources and conflicts within the watershed is not co-ordinated and the balance between these dimensions of demand within the Kouris watershed has not been met. There is a need for a new approach to water management in Cyprus, which takes into consideration the pertinent contextual factors: (1) imbalance of growing demand and exhausted/costly supply; (2) growing environmental costs and

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issues of sustainability; (3) watershed-level water management and river basin districts; and (4) fragmented legal and institutional framework.

In short, the unregulated interplay of water-using agents acting in their own interests has led to conflicting demands within the watershed. The management of water resources has not taken a watershed approach, has been uncoordinated, and the balance between demands within the Kouris watershed has not been met. As a result the water balance for the SCP is in deficit and, given the expected sectoral growth, is likely to worsen in the coming years, whilst environmental impacts go largely unchecked. The development of conventional water sources has proved insufficient for securing water resources in the face of extreme climatic conditions and the options for supply augmentation are nearly exhausted and only available at high cost. An integrated approach is needed.

4. EVALUATION OF WATER DEMAND IN CYPRUS

4.1 Residential Household Water Demand

An analysis of residential water demand from the SCP was undertaken. Water demand was calculated from expenditure data and knowledge of the tariff structure in each of the localities. As in most European countries and in the USA, Cyprus water utilities choose among three types of pricing schemes (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 on the island.

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 modelling 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.

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We estimated a model consistent with fundamental principles of the economic theory of consumer behaviour (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 estimate demand for water using individual household data. Lower rank demand systems are unable to capture the non-linear income effects pertaining to these data. Second, we need a demand system that satisfies integrability (that is, the ability to recover the parameters of the indirect utility function from empirical demand analysis), because we plan to analyse 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 in Cyprus based on political-economic arguments.

The theoretical model described above is applied to individual household data from the 1996/97 Family Expenditure Survey (FES) of Cyprus. This allows estimation of the price and income elasticities of residential demand for water in Cyprus, the marginal value of water in the residential sector and evaluates the welfare effects associated with changes in the water-pricing system. Empirical results show that the current water-pricing system is progressive, but inefficient in the sense that it introduces gross price distortions resulting in deadweight loss. The regional difference, in particular, 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 on a small island like Cyprus such large regional differences in price can reflect differences in supply costs. The regional price heterogeneity can also not be justified on equity grounds, because we found that large water consumers pay a lower average price per cubic metre than users consuming smaller amounts of water.

The empirical analysis suggests that the marginal value of water in the residential sector is £CY0.45/m^3. The price elasticity of water demand ranges between -0.4 for households in the lowest and -0.8 for households in the highest 10 per cent income distribution (see Table 14.2). This means that the demand curve for water is downward sloping and highly responsive to price changes for high-income water users. This suggests a strong role for price as a demand management tool. Budget elasticities for water, which reflect the responsiveness of the proportion of income spent on water to income changes, and hence income elasticity of demand (IED), are also

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Table 14.2 Estimated price and budget elasticities of household water demand

Elasticity	Income group percentiles					
	Bottom 10%	11–25%	26–50%	51–75%	76–90%	Top 10%
Budget	0.25	0.22	0.23	0.30	0.35	0.48
Price	−0.79	−0.69	−0.60	−0.56	−0.50	−0.39

Source: Hadjispirou et al. (2002).

shown in Table 14.2. The fact that the budget elasticities are always less than 1 implies that water is, as expected, seen as a necessity. However, the value increases with income, suggesting that an increase in income for high-income households leads to a greater increase in the proportion of income spent on water. This can be explained by the fact that higher-income groups use more water for water-intensive luxury goods such as swimming pools and gardens with lawns.

The analysis showed that the existing and regionally defined heterogeneous increasing block pricing system introduces gross price distortions that cannot be justified on the basis of efficiency considerations. In the case of residential water use, price can play a role in 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.

4.2 Agricultural Water Demand

An agricultural production function for groundwater users was estimated econometrically from which the marginal productivities of the inputs as well as the effects of each of the inputs on risk could be derived. Risk considerations are necessary in the understanding of the agricultural sector's use of water. Public policy should consider not only the marginal contribution of the various inputs to the output, but also the marginal reduction in the variance of the output.

In the estimated production function, fertilizers, manure and pesticides (FMP) inputs, as well as water, had a significant and positive effect on expected profit. These FMP inputs and water exhibit decreasing marginal returns. Water and FMP and labour and FMP appear to be complimentary

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Table 14.3 Estimated risk premiums and marginal input productivity

Parameter	Water			Fertilizer			Labour		
Average risk premium (% of expected profit)	18			19			17		
Impact on variance of profit (other inputs constant)	Positive and decreasing			Positive and decreasing			Negative and decreasing		
	Citrus	Veg	Cereal	Citrus	Veg	Cereal	Citrus	Veg	Cereal
Marginal productivity by crop (CY£)	0.59	0.21	0.14	0.72	0.55	—	0.17	−0.32	0.25

Source: Groom et al. (2002).

inputs. Water and FMP are risk increasing inputs, but at a decreasing rate. On the contrary, labour appears to decrease the variance of profit at an increasing rate (see Table 14.3).

Crop-specific production functions are found to be statistically different and have better explanatory power than a general agricultural production function in the Kiti region. This indicates that crop specific policies will be more efficient than policies, which do not differentiate among crops. In addition, for all crops fertilizers and pesticides exhibit higher marginal contributions than either water or labour.

Farmers exhibit moderate risk aversion and are willing to pay approximately one-fifth of their expected profit to achieve a situation in which the profit received with certainty leaves them as well off as the uncertain expected profit. No heterogeneity in risk attitudes is observed across the farming population, so policies introduced to reallocate risk do not need to differentiate between specific types of farmers. This is reasonable given the fact that the agricultural region under consideration is small and there exists almost no variation in the accessibility of economic resources, services and information.

4.3 Environmental Water Demand

As the standards of living increase in Cyprus, so water demand for recreational purposes also increases. Furthermore, water may have a use value, but also a non-use or existence value. People who are willing to pay for water and wildlife preservation can be local residents who live near a wetland, for example, but also people who care about its preservation and live far away from it. In a separate study, the willingness to pay (WTP) for

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environmental goods that are dependent upon freshwater resources, that is, wetland ecosystems, which provide an important habitat for migratory bird species in Cyprus, was estimated.

Possible non-use values were estimated using the contingent valuation (CV) methodology in the context of water provision for migratory bird species (Swanson et al., 2001). The valuation scenario used was a real one: without regional co-operation, a migratory bird species, which uses wetlands in Cyprus and the UK as a habitat and migratory stepping stone, the white-headed duck, will be threatened with extinction. Those surveyed were asked to express their preferences for the provision of water to endangered species under co-operative and non-cooperative funding scenarios. Econometric analysis of the survey responses demonstrated that there exists a positive WTP for the provision of local water to the endangered species of £10 per household per year. It is further demonstrated that there is an increased WTP of £10 plus an extra £5 per household per year for the local allocation of water to the endangered species if other states along the migratory route make similar choices (the co-operative scenario).

4.4 Optimal Groundwater Management

This study looks at the particular issues of optimal groundwater management and the allocation of groundwater between competing agricultural and residential demands. Optimal allocation of groundwater is a multi-stage decision process. At each stage, for example, each year, a decision must be made regarding the level of groundwater use, which will maximize the present value of economic returns to the basin. The initial conditions for each stage may be different due to changes in either the economic or hydrologic parameters of the basin under consideration. However, in most of the dynamic models employed in the groundwater literature the resource is modelled as a stock to be depleted in a mining era before moving to a stationary state era. Implicit in these models are the assumptions of fixed economic relations and/or exogenous rates of change through time.

More complex and realistic representations of increasing resource scarcity incorporate opportunities for adaptation to rising resource prices. That is, in the long run, shifts away from water intensive production activities, adoption of new techniques or backstop technologies, substitution of alternative inputs, and production of a different mix of products offer rational responses to increasing scarcity. To model these, economists have developed the technique of multi-stage optimal control in the context of groundwater mining for agricultural production. Our study employs this

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technique to describe the chronological pattern of groundwater use by different economic sectors (residential and agriculture) in order to define the optimal quantity of the resource that should be produced when the available backstop technology (that is, seawater desalination) is adopted at some endogenously defined time. Included in a control model this type of adaptation strengthens its ability to describe economic processes associated with natural resource depletion. The additional information can further inform public policy decisions concerning natural resource allocation among economic sectors, optimal timing of adoption of an available backstop technology and definition of the optimal quantity of the resource to be produced by this technology for each of the different users.

Moreover, our model takes into account common property arrangements for groundwater resources that lead to dynamic externalities in consumption. These externalities are associated with the finite nature of the resource, pumping costs and the use of groundwater as a buffer against risk. Our study focuses upon the common use of the Kiti aquifer and addresses the scarcity rents generated by agricultural and residential demand for groundwater. The optimal allocation between agricultural and residential sectors is simulated based on hydrological parameters and the corresponding optimal unit scarcity rents are calculated. The optimal scarcity rents are compared to those that emerge under the simulated myopic common property arrangement, the difference reflecting the common property externality, allowing us to assess the benefits from optimal groundwater management, through, for example, more adequate and incentive groundwater pricing.

Our results suggest that in the presence of a backstop technology the effect of the dynamic externality in groundwater consumption is not particularly strong on the social welfare of the economic sectors using groundwater. This is an intuitive result, because it suggests that when the scarcity of the resource is reduced due to the presence of a backstop technology, welfare gains from controlling resource extraction are not significant for any practical purposes. However, in the absence of a backstop technology and continuous natural recharge, the effect on welfare from managing groundwater extraction is significant. A huge welfare improvement is derived from controlling extraction as compared to myopic exploitation of the aquifer (see Table 14.4).

Finally, an alternative methodology, the distance function approach, is employed to estimate the scarcity rents of the Kiti groundwater using more applicable behavioural assumptions for agricultural firms. Distance functions have a number of virtues, which make their use attractive when the environment under which firms operate is regulated and/or firms are inefficient due to a lack of incentives faced by their operators. In particular, the first virtue of distance functions is that they do not necessarily

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Table 14.4 Welfare and welfare improvement under the optimal control and common property regime

Regime	Backstop	Welfare	Welfare improvement
Optimal control	Available	£170.360 m	
Myopic	Available	£162.621 m	3.8%
Optimal control	Not available	£110.510 m	
Myopic	Not available	£25.9610 m	409.4%

Source: Koundouri (2000).

require price data to compute the parameters. Only quantity data is needed. Secondly, distance functions do not impose any behavioural hypothesis (such as profit maximization or cost minimization). They allow production units to operate below the production frontier (that is, to be inefficient) and they also allow derivation of firm-specific inefficiencies. Thirdly, duality results between distance functions and the more conventional cost, profit and revenue functions provide flexibility for empirical applications.

The key extension of this research compared with existing theoretical literature is that, if cost, profit or revenue function representations are precluded, the restricted distance function provides an excellent analytical tool for estimating unobservable shadow prices of *in situ* natural resources (produced and used as inputs in production processes of vertically integrated firms). The data used in this research were based on the Production Surveys conducted by Koundouri and Xepapadeas (2003; 2004) for the years 1991, 1997 and 1999. Our analysis focuses on a sample of 228 agricultural farmers located in the Kiti region. The data set consists of a balanced panel composed of the same 76 farmers over the three years of the survey. Estimation suggests that firm specific efficiencies are increasing over time. The average technical efficiency for agricultural firms in the sample increased rather rapidly from 0.47 in 1991 to 0.78 in 1997 and finally to 0.94 in 1999, where a coefficient of 1.0 would represent a firm at the frontier of efficiency.

The reported increases in the technical efficiency of agricultural firms can be attributed to the major restructuring of the agricultural sector in the last decade in an attempt to harmonize the Cypriot agricultural policies with those of the European Union (EU) in the light of Cyprus accession in the EU. Alternatively, increases may indicate the existence of technological progress in the agricultural sector, which is not accounted for in our empirical model (which assumes constant technological change). These are the

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Table 14.5 Resource rents under the optimal control and common property regime

Component of social cost	Optimal control (£Cy/m^3)	Common property (£Cy/m^3)
Groundwater pumping cost	0.31	0.31
Scarcity rent/marginal user cost	0.20	0.0097
Marginal social cost of groundwater	0.5*	0.32

Notes: * Cost of the backstop technology desalination.

first estimates of the efficiency of the Cypriot agricultural sector and, as a result, there is no scope for comparison at present. The key outcome of this empirical application, however, is that estimated technical firm specific inefficiencies present in agricultural production technologies, suggest that cost minimization is not the relevant behaviour objective in irrigated agriculture in Cyprus. This result provides support for the use of the distance function approach to derive resource scarcity rents.

The unit scarcity rent of *in situ* groundwater estimated by the distance function is approximately equal to zero (0.0097 CY£/m^3) under the myopic common property scheme (Table 14.5). This is approximately 20 times less than the same value under optimal control. This comparison indicates that agricultural producers in the region are not paying the full social cost for groundwater extraction. This implies that under common property, externalities arise as current users of the resource are only paying the private cost of their resource extraction. As a result, the resource's scarcity value remains unrecognized (Koundouri, 2003). This pattern of behaviour is consistent with perfect myopic resource extraction, which arises because of the absence of properly allocated property rights in groundwater and is consistent with the results found in a study on WTP for groundwater quality.

A hedonic analysis of WTP for improvements in groundwater quality was also undertaken. Groundwater quality may affect the productivity of land used for cultivating crops. Where this is so, the structure of land rents and prices are expected to reflect these environmentally determined productivity differentials. Hence, by using the collected data on land rent or value for different properties, we tried to identify the contribution of fresh groundwater quality to the price of land and therefore WTP for groundwater quality.

Based on this approach, the estimated marginal value of groundwater quality as far as reduced salination is concerned is statistically insignificant and equal to £CY1.07 per hectare of land (Koundouri and Pashardes, 2002).

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The statistically insignificant small marginal WTP for improvements in groundwater quality may imply that groundwater extraction is myopic, for instance, because of free-riding. This is expected to be an artefact of the non-existence of properly allocated property rights in a common-pool aquifer.

Another explanatory factor for the low marginal WTP for groundwater quality may be a substitution effect of farmers changing their land use to the more lucrative tourism industry. Tourism utilizes other existing water sources than groundwater.

5. BALANCING THE COSTS AND BENEFITS OF AN OPTIMAL WATER ALLOCATION AND THE CORRESPONDING POLICY IMPACTS

An optimal allocation of scarce water resources in Cyprus requires a careful balancing of the various values of water within the catchment area. In Cyprus, the preferred method for implementing the optimal allocation was through the development of a uniform water-pricing scheme where each water user is charged the same price. Hence, water pricing for residential, agricultural and environmental uses was taken into consideration and based on the marginal social cost of water supply. The marginal social cost of water supply was estimated at £CY0.45/m^3 by the Water Development Department in Cyprus, using the average incremental cost methodology and reflecting the long-run marginal cost of water provision based on the national resources required for its provision. The marginal social cost of water equals the opportunity cost of providing additional water for different purposes in Cyprus rather than providing other socially demanded goods and services (such as health services or education services) on the island. The marginal social cost of water provided to the charged residential and industrial sectors should also reflect the opportunity costs of losing water to the uncharged (public good) sector. The analysis of the value attached by the public to water allocation for the preservation of wetlands as a habitat and stepping stone for endangered migratory bird species has demonstrated that there exists a positive WTP for these non-priced and water-dependent environmental resources. The marginal social cost of water charged to residential and industrial sectors should in fact reflect the costs of all opportunities forgone as a result of a specific allocation of water.

However, there may also be other important factors, which have to be taken into consideration under this optimal allocation, such as equity (the impacts on lower income groups), risk (the impacts on variability) and

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hydrology (the impacts on conjoint users). The household demand study showed that the current increasing block pricing system introduces price distortions, which cannot be justified, either on efficiency or equity grounds. In terms of efficiency the current tariff system cannot be justified, because the same water resource supplies all locations at similar marginal social costs. Since large water consumers pay a lower average price than small water consumers, the current tariff system can also not be justified on equity grounds. Although a shift towards a uniform marginal cost pricing system will eliminate the deadweight loss of the current system, its benefits will be distributed in favour of the better off households. As such the water-pricing policy can be considered inequitable. The impact of water availability on the variance in producer profitability was also analysed, showing how the current and an alternative water allocation affects the welfare of risk-averse agents. We discovered that water has a positive, but decreasing effect on the variance of profit. Other things remaining equal, this implies that although additional water use increases the output and profit on average (that is, positive marginal productivity), it simultaneously increases the risk associated with the produced output. The analysis shows that the population is risk averse, and therefore additional water use may be welfare reducing.

An important concern was furthermore related to a possible reduction of agricultural subsidies and the expected impact that this may have on employment. However, the estimated production function showed no significant complementarity between labour and water input, indicating that a change in water use will not have any effect on current employment in the agricultural sector.

The logic behind treating the watershed as the most appropriate management unit is that the interactions of the physical elements of hydrology and geo-hydrology and water demand can be addressed in a coherent way and can guide policy. However, thus far the interdependent nature of surface water and groundwater, and the wider impacts that demand for one of these resources has upon the other, has been largely ignored in our study. Any policy impact analysis should consider the interdependency between and conjoint use of groundwater and surface and their mutual impacts. Excessive groundwater pumping reduces, for example, surface water flows downstream and hence the available water for the sectors located there. On the other hand, groundwater pumping may contribute to surface water flows through return flows, increasing the importance of the timing of resource flows. Seasonal pricing could be used to ensure water availability to downstream users in line with their seasonal preferences.

Finally, the proposed allocation of water needs to be backed up by legislative change. Water legislation in Cyprus is characterized by a piecemeal

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approach (see the appendix to this chapter). The quality of freshwater resources is dealt with in several laws, depending on resource type and specific water use. Moreover, both water quality and water quantity aspects are dealt with through several different instruments, in particular in the case of groundwater. A more integrative approach is expected in the near future as a result of the implementation of the European WFD.

In sum, the foregoing has provided an example of how CBA of water policy can be structured in the context of the much discussed hydrological unit: the watershed. The methodology and case study combine to show how the constraints faced by watershed managers and policy-makers can be usefully evaluated and traded off using the principles of CBA and how, using economic analysis in conjunction with legal and hydrological backdrop, important considerations or environment and equity can be incorporated into the policy-making process.

APPENDIX

Brief Overview of the Institutional and Legislative Background to Water Policy in Cyprus

Generally speaking, the institutional arrangement to protect freshwater resources in Cyprus is characterized by a fragmented, piecemeal approach, involving the Council of Ministers, the Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment, the Department of Labour of the Ministry of Labour and Social Insurance and the Medical and Public Health Services Division of the Ministry of Health (Grimeaud, 2001).

Water legislation in Cyprus has three main components:

1. *Legislation on the protection of freshwater resources surface and groundwater*. The 1991 Control of Water Pollution Law [69/91]. Regulations include: 1992 and 1995 Regulations on Application for a Licence relating to Waste Disposal; the 1993 Regulation on the Prohibition of Discharges; the 1996 Order on Measures for the Protection of Underground Waters and a Code of Good Agricultural Practice.
2. *Specific legislation on groundwater*. The 1928 Government Waterworks Law and the 1946 Wells law. This arranges, *inter alia*, that groundwater which has not yet been subject to abstraction and exploitation [as well as waste water] falls under state propriety.
3. *Legislation on water supply*. This aims at maintaining an appropriate level of water quantity in certain sensitive aquifer areas and at providing

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consumers with tap water in sufficient quantity. There are three main pieces of legislation: (a) 1955 Water Development and Distribution Law, (b) 1964 Water Supply law and (c) 1951 Water Supply law.

The implementation of legislation concerning the protection of water resources is the responsibility of two different ministries. The Ministry of Agriculture, Natural Resources and the Environment sets Environmental Quality Standards, grants permits for discharges and enforces all provisions related to pollution from industrial sources, while the Ministry of Labour and Social Insurance is in charge of monitoring and compliance with permit conditions. Legislation regarding water supply is implemented by Water Development Committees, which are established to promote the conservation of water resources, to develop the use of those resources and to co-ordinate water supply distribution. Moreover, they may also regulate the use of water and prevent waste discharges. The Council of Ministers designates water shortage areas for which permits have to be obtained prior to the construction of wells or the exploitation of surface water.

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