The Economics of Water Resource Allocation: Valuation Methods and Policy Implications

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2011

Metadata of the chapter that will be visualized online

Series Title	
Chapter Title	The Economics of Water Resource Allocation: Valuation Methods and Policy Implications
Chapter SubTitle	
Copyright Year	2011
Copyright Holder	Springer Science+Business Media B.V.

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Abstract	In this chapter a ‘watershed economics approach’ that could be applied in Cyprus is proposed which is composed of two important stages. In Stage I 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 objective balancing of demands based upon the equi-marginal principle to achieve economic efficiency. In Stage II 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.

Keywords (separated by '-')	Watershed economics approach - Economic valuation techniques - Balancing demands - Social equity - Kouris watershed

Chapter 7
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Ben Groom and Phoebe Koundouri

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Introduction

How is it possible to allocate water in Cyprus 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. Firstly, water is a necessity

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P. Kounouri (ed.), *Water Resources Allocation: Policy and Socioeconomic Issues in Cyprus*, DOI 10.1007/978-90-481-9825-2_7,

for human existence. The absence of clean drinking water and sanitation leads to health problems, whilst the lack of access 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 (e.g. the degradation of wetlands and coastal fisheries, depletion of aquifers, and loss of watershed services) (FAO 1987; Winpenny 1991). 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 (e.g. Winpenny 1994).

It is our belief that a more balanced approach to water resource management in Cyprus must ensure that scarce water resources are allocated between competing demands in a way that maximizes their contribution to societal welfare. We further believe that this approach must be constructed in a way that considers its impacts on all of the various groups and interests affected. This requires the integration of various approaches and perspectives into a single systematic framework. We believe that a coherent watershed-based resource allocation methodology is required. This approach is especially useful in Cyprus due to the interaction of various water resource allocation issues.

In what follows a 'watershed economics approach' that could be applied in Cyprus is proposed which is composed of two important stages. In Stage I 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 objective balancing of demands based upon the equi-marginal principle to achieve economic efficiency. In Stage II 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.

Balancing the Demands for Water Resources: The Methodology

The methodology we propose for application to the underlying problem of watershed management 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; (5) the assessment of the impacts of the proposed reallocation.

The Management Unit: Watershed

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 the following broad reasons. First, the aggregate availability of water resources, including sustainable yields is bounded by the hydrological cycle of the watershed. Second the interaction of different sources: e.g. 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 are defined by the watershed. Finally, an understanding of the hydrological cycle in the watershed area in question is a pre-requisite for the determination of efficient, equitable and sustainable water resource allocation.

The Allocation Objectives

The methodology proposed provides the policy maker and planner with an objective 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 maximise societal welfare from a given natural resource base subject to those valuations. The key objectives of public policy in the allocation of resources are economic efficiency, social equity and environmental sustainability. 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). 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. 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. 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.

Stage I of Methodology: Objective Approach to Balancing Water Demands

The first step towards the application of Stage I of the methodology is the evaluation of demand, by applying appropriate methodologies to assess characteristics of the demand for water arising from individual, sectoral and environmental uses. This allows the derivation of the parameters of water demand required for policy purposes: Marginal Value, Price Elasticity, Income Elasticity, Willingness to Pay and risk parameters for all the relevant dimensions of demand (see Appendix). The evaluation process should be undertaken in accordance with carefully constructed methodologies, and be independent of any prior rights to water resources. This enables an evaluation of water uses according to the benefits that accrue to all of society from them. The overall evaluation strategy is shown in Fig. 7.1 below.

The second step of stage I, focuses on the determination of efficient allocations through the evaluation of the relative values accruing to society by virtue of differing water allocations. This entails the determination of those water allocations that achieve an economically optimal balance. An economically optimal allocation is one in which aggregate demands are balanced with supply according to the equation of marginal social value (benefit) to the marginal social cost of supply, and in which each source of demand is achieving equal value from its marginal allocation of water.

To complete the third step of stage I of the methodology one need to ascertain the impacts of implementing the efficient allocation. The policy maker may choose from a wide variety of instruments to affect the desirable allocation (tradable permits, pricing, auctions). Any proposed method of implementation should be considered for feasibility within the relevant watershed, and then evaluated for its broader impacts on the society. This evaluation process leads into Stage II of the Methodology.

Stage II of Methodology: Policy Impact Analysis

First, one should focus on the effects of Stage I on welfare distribution. The impact of the allocation policy options should be evaluated to establish the resulting distribution of the costs and benefits to society. That is, the change in social deadweight loss resulting from resource allocation changes should be determined, together with the actual distribution of this change. This is important both from the perspective of equity and often for reasons of political economy.

Consideration of sectoral demands in isolation may be insufficient to ensure efficient outcomes. Where water users are conjoined by the underlying hydrology of the watershed there are a number of potential impacts/externalities that may arise from the chosen allocation. For example, policies implemented in upstream areas of a watershed will impact upon downstream users where the water resources are conjoined. Ignoring these effects will lead to inefficient allocations of water. In effect sectoral, spatial and temporal allocation of water demand should be considered, as well as other externalities that arise from the demand for public goods, which

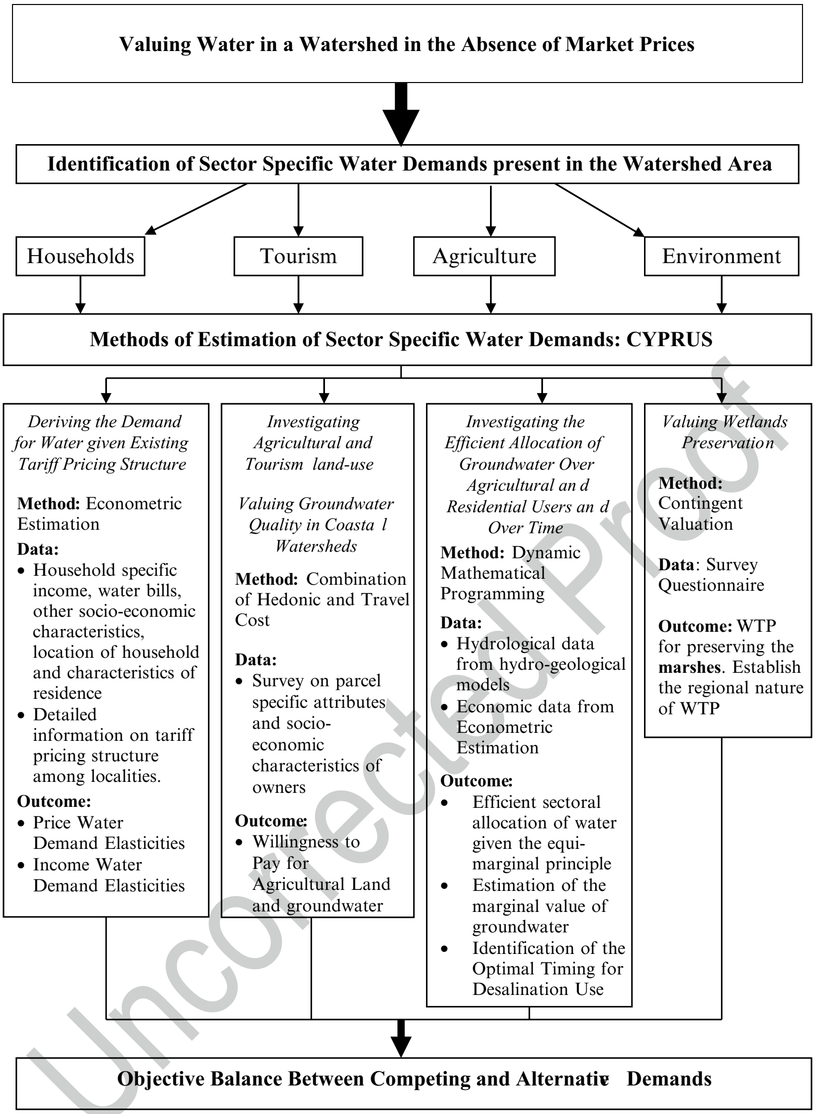

Fig. 7.1 The methodology for water demand valuation in a watershed area: examples from the Kouris watershed in Cyprus

frequently extends beyond the watershed. Global and regional environmental goods for which existence, bequest and option values are held provide an example of this. Furthermore, where water scarcity is extreme, demands for water outside the watershed may induce investments in inter-basin transfers.

Finally, as one of the main obstacles to water re-allocations a review of the legislative and institutional environment required to effect the desired allocation may be required.

Case Study: Kouris Watershed in Cyprus

The following study illustrates how the economic watershed appraisal methodology described above has been implemented in Cyprus. It uses the Kouris watershed as an example of a watershed in which resource conflict exists, describes how valuation exercises have been undertaken in Cyprus for the sectoral demands, and the policy implications. In Section Case Study: Kouris Watershed in Cyprus we set out the nature of the water management problem being investigated in Cyprus.

Overview of Human and Physical Aspects: Hydrology and Water Supply

Cyprus is an arid island state situated in the north-eastern Mediterranean 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. For more details on the hydrological conditions in Cyprus, see Chapters 2, 3 and 8 of this volume.

A number of different water supply investments and interventions have been made in Government controlled Cyprus. In addition to surface water dams and groundwater exploitation, these have included recycling, desalination, and even evaporation suppression, cloud seeding and importation of water. Table 7.1 shows the contributions to water supply of the most important water resources and investments.

The most significant investments, as indicated in previous chapter of the book (mainly Chapter 2) 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. Currently all aquifers are exploited beyond their safe yield, with the excess of use over natural recharge estimated to be 40 Mm^3/a.

Sectoral Water Consumption

The inter-sectoral demand for water is shown in Table 7.2 for the three major water schemes in Cyprus. It can be seen that approximately 75% of current water use is in irrigated agriculture. The majority of the remaining demand is in urban areas including municipal, tourist and industrial demands.

There is a distinct seasonality to the demands for water from both of 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% over the past 15 years, driven largely by up to 10% annual growth in the tourist sector. There has also been nominal 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% over the 1980–1992

Table 7.1 Water resource assessment, Cyprus (Socratous 2000)

Water source	Average quantity (Mm^3/a)	Description
Surface Water	130–150	Diverted to storage dams; subject to evaporation
	150	Diverted direct from rivers for irrigation
Groundwater	270	Pumped or extracted from springs
Desalination	6.5	Supplies residential areas: capacity to increase
Recycling	4	Planned to be increased to 13 Mm^3/a

Table 7.2 Water consumption in the major water schemes in Cyprus, MCM/a (1994)

Water scheme	Municipal, industrial 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

Adapted from World Bank (1996)

period. Coupled with an expected aggregate population growth rate of 0.9% and rapid urbanization, these different components of sectoral growth will place further pressure on water resources in the years to come. These factors describe the inter- and intra-temporal aspects of water demand.

Price is a significant determinant of water consumption. The consumption of water resources by irrigated agriculture is subsidized to the tune of 70% of the unit production cost on average (World Bank 1995). Current pricing strategies in urban areas differ significantly between municipalities, but generally involve significant cost recovery.

The Water Balance, Rights to Resources and Institutional Background

A quick comparison of the estimated water resource availability and demand predictions contained in Tables 7.1 and 7.2 suggests that the overall water balance in Cyprus is favorable on average. However, given the spatial and temporal variability of water resources and demands described above, the water balance itself varies from one watershed and/or water scheme to the next and from 1 year to the next. The scarcity of water resources in Cyprus is thus characterized by extreme fluctuations over time and space of water supply and demand: including droughts, and not in general by the average hydrological parameters.

Of the water schemes shown in Table 7.2 the SCP has been shown to have the least favorable water balance (World Bank 1995). Using recorded levels of

Table 7.3 Water balance for the Southern Conveyor Project

Demand and supply		1995	2000
Water Supply	Surface water	61.8	61.8
	Groundwater	28.0	28.0
	Diversions	16.3	16.3
	Desalination	–	6.5
	Reuse	1.0	7.0
Total supply[a]		101.1	109.6
Water Demand	Urban	42.7	48.9
	Irrigation	45.9	61.2
Total demand		88.6	110.1
Water balance		12.5	–0.5

[a]Net of evaporation: 6 MCM/a. Source World Bank (1996)

consumption for the area supplied by the SCP, and comparing these to the water supplied from desalination, recycling and the recorded surface water inflows for the period 1969–1994 the water balance in Table 7.3 is constructed.

The SCP caters for 40% of the aggregate demand; 80% of all urban demand and 25% of all agricultural demand. Clearly, the average water balance for the SCP scheme is negative based on the surface water flows witnessed over the 25 year period and the observed water demands. It is the deficit of surface water flow where the main shortfall occurs. Given the yearly fluctuations in precipitation and the resultant surface flow, the picture of scarcity and the severity of the deficit varies from year to year. With demands at 2,000 levels, the pattern of surface water flows observed over the past 25 year period would lead to several years of water deficit, many of which would be severe. Indeed the droughts of 1989–1991 and 1995–1999 illustrate the immediacy of the water balance deficits and the potentially unsustainable path of water resources management under the current system.

In summary, the uncertainty and variability of water resources heightens the need to store water to smooth resource availability in order to supply seasonal demands. The need for smoothing of water supplies has given rise to large investments in surface water storage dams, water transfer schemes such as the SCP, and placed pressure on natural storage in groundwater aquifers. Inter-temporal and spatial dimensions to water scarcity, coupled with expected growth in the industrial, household and tourist sectors, and from the heavily subsidized agricultural sector, have given rise to a situation in which the options for water supply augmentation are either exhausted or high cost. The deficit of the water balance can only be expected to worsen.

With regards to institutional and legislative background, as well as the property rights to water resources, as discussed in detail in Section Stage 1: The Evaluation of Water Demand in Cyprus (also commented upon in all chapters of this book), the current property rights are in part based on the riparian principle and the 'rule of capture' (first in time first in right) and the resulting pattern of demand is uncoordinated. 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.

The Need for a Policy Change

The current water balance in the Southern Conveyor Project 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 may be illustrated by the case of the Kouris catchment. It is widely believed that the unchecked 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 1995). 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 coordinated and the balance between these dimensions of demand within the Kouris watershed has not been met. Balancing of demand with the natural constraints of water supply in Cyprus requires an approach that analyzes the constituent determinants of the prevailing demand and supply imbalance in a manner which is hydrologically coherent and which recognizes the competing demands for water resources. An integrated approach is required.

Applying the Principles to the Kouris Watershed

Background to the Kouris Watershed

The Kouris watershed covers 300 km^2 in the South West of Cyprus. The watershed contains storage dams with a total capacity of 180 MCM and provides much of the surface water for the Southern Conveyor Project (SCP). The largest single storage dam is the Kouris Dam, with a capacity of 115 MCM. 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 centers, 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. An investigation of the Hydrology of the Kouris watershed is provided in Table 7.4.

Diversions of surface flow upstream reduce the surface water flow available downstream. Similarly it has been found that surface water flow is coupled with groundwater; up to 60% of the surface water flow is made up of sub-surface flow and springs. The use of one resource impacts upon the other (Boronina et al. 2001).

Table 7.4 The hydrological analysis of the Kouris catchment

Task	Sub-task	Detailed description
Data collection and manipulation	1. Rainfall data	Precipitation for the period 1970–1995 was established in annual and 5-year moving average terms for specific meteorological stations
	2. Correlation of rainfall with spring discharge	The correlation between rainfall and surface flow (spring discharge and river discharge), was established for the period 1984–1995 by spring and by river/tributary. A strong correlation was found using an exponential trend line
	3. Correlation of rainfall with river discharge	
	4. Evapo-transpiration	Measurements of evapo-transpiration at different altitudes were taken using evaporation pans
	5. Water depth observations	Water depth observations for the period 1984–1995 were established for a variety of boreholes. The period corresponded to a non-pumping period and the water levels showed a general increase
	6. Aquifer properties	The description of the aquifer was based on pumping tests and lineament analysis. From this transmissivity was estimated
Mapping	1. Borehole location	A borehole map was prepared indicating the location and density of boreholes, and those boreholes for which water level measurements had been consistently taken. Drilling records from 166 boreholes were available
	2. Meteorological and gaging stations	The location and density within that location of meteorological and gaging stations was mapped.
	3. Geology and springs	The location and flow of permanent springs was mapped onto the Geological map of the catchment
	4. Transmissivity and piezometry	Maps were developed describing the piezometry and the transmissivity of the aquifers in the catchment
Simple water balance model	1. Water balance: Inflow = outflow + changes in ground water storage	Information regarding the transient surface water flows and aquifer behavior was combined with the assumptions regarding the abstraction of water in the Kouris catchment to obtain a simplified water balance
	2. Surface water groundwater relation	Initial analysis of the interaction of surface water and groundwater revealed that 65–70% of the stream flow in the catchment consists of base flow and stream discharge

Adapted from Boronina et al 2001

Under these circumstances it is clear that the decisions of upstream water users impact upon downstream users. Indeed, it is widely believed that the unchecked 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 1995). 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 for migratory bird species.

In sum, 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. The need for water demand management is clear in this situation.

Stage 1: The Evaluation of Water Demand in Cyprus

In what follows we describe the various sectoral demand assessments that have been undertaken in Cyprus and present the results.

Household Demand Assessment

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 the United States, 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 in the island.

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.

We estimate a model consistent with fundamental principles of the economic theory of consumer behavior (Hadjispirou et al. 2002). We choose the Quadratic Almost Ideal Demand System (QUAIDS) model for the following reasons. First, we estimate demand for water using individual household data for which lower rank demand systems are to be inadequate to capture the non-linear 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 in Cyprus based on political economy arguments.

The theoretical model described above is applied to individual household data, contained in the Family Expenditure Survey (FES) of Cyprus 1996/1997. 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 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 that users consuming much smaller amounts of water.

Moreover, the empirical analysis suggests that the marginal value of water in the residential sector is CYP 0.45/m^3. The price elasticity of demand for water ranges between – four for households in the lowest and – eight for households in the highest 10% of income distribution (see Table 7.5). This means that the demand curve for water is downward sloping and for high-income water users, highly responsive to price changes. This suggests a strong role for price as a demand management tool. As indicated by the estimated elasticities, water is complementary to water intensive luxury goods such as swimming pools and gardens with lawns.

The analysis found that current regionally heterogeneous increasing block pricing system in the island introduces gross price distortions that are not justified.

Table 7.5 Estimated household price and budget elasticities of demand for water

	Income group percentiles					
Elasticity	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

Koundouri et al (2000a) [AU1]

Thus 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.

Estimating the Scarcity Value of Groundwater: Quantity

Optimal allocation of groundwater is a multistage decision process. At each stage, e.g. 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.

Complex and realistic representations of increasing resource scarcity incorporate opportunities for adaptation to rising resource prices. That is, in the long-run perspective, 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 multistage optimal control in the context of groundwater mining for agricultural production. Our study (Koundouri 2004) employs this technique to describe the chronological pattern of groundwater use by different economic sectors (residential and agriculture) in order to define optimally the quantity of the resource that should be produced when the available backstop technology (seawater desalination) is adopted at some endogenously defined time. Including in a control model the opportunity for this type of adaptation strengthens its ability to describe economic processes associated with natural resource depletion. The additional detail, further can inform public policy decisions concerning natural resource allocation among economic sectors, optimal timing of adoption of an available backstop technology and definition of optimal quantity of the resource to be produced by this technology for each of the different users.

Moreover, our model takes in 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 buffer against risk. Our study focuses upon the commonality 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 incorporating hydrological parameters and the optimal unit scarcity rents are derived. The scarcity rents are compared to those that emerge under the simulated myopic common property arrangement, the difference reflecting the common property externality, and the benefits from optimal groundwater management, e.g. pricing, are assessed.

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.

Lastly, an alternative methodology, the distance function approach, is employed to estimate the scarcity rents of the Kiti groundwater using more applicable behavioral assumptions for agriculturists (Koundouri and Xepapadeas 2004). The first virtue of distance functions is that they do not necessarily require price data to compute the parameters; only quantity data is needed. Secondly, distance functions do not impose any behavioral hypothesis (such as profit maximization or cost minimization). That is, they allow production units to operate below the production frontier (i.e. 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.

Given that technical change is assumed to be constant in the estimated model over the relevant time period, these results allow the conclusion that the managers of the agricultural firms in the sample under consideration, learn from their previous experience in the production process and as a result their technical inefficiency effects change in a persistent pattern over time. The reported substantial increases in the technical efficiency of agricultural firms can be attributed to the major restructuring of the agricultural sector that took place in the last decade in an attempt to harmonize the Cypriot agricultural policies with those of the European Union, in the light of Cyprus accession in the EU. Alternatively, increases may indicate the existence of technological progress in the agricultural sector under consideration, which is not accounted for in our empirical model. These are the first estimates of the efficiency of the Cypriot agricultural sector and as a result there is no scope for comparison at the present. The central result of this empirical application, however, is that estimated technical firm-specific inefficiencies present in production technologies of agricultural, suggest that cost minimization is not the relevant behavior objective in Cyprus irrigated agriculture. 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 CYP/m^3) under the myopic common property. This is approximately 20 times less than the value under optimal control. This comparison indicates that agricultural producers in the region are not willing to pay the full social cost of their extraction. This implies that under common property, externalities arise, as current users of the resource are willing to pay only the private cost of their resource extraction, and as a result the resource's scarcity value goes completely unrecognized. This pattern of behavior 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 on WTP for groundwater quality.

Estimating the Scarcity Value of Groundwater: Quality

A hedonic analysis of the willingness to pay (WTP) for improvements in groundwater quality is undertaken. Groundwater quality may affect the productivity of land used for cultivating crops (Koundouri and Pashardes 2003). Where this is so, the structure of land rents and prices will reflect these environmentally determined productivity differentials. Hence, by using the collected data on land rent or land value for different properties we can in principle identify the contribution which the attribute in question, fresh groundwater quality, makes to the price of the traded good, land. This identifies the WTP for groundwater quality.

The estimated marginal producer's valuation for groundwater quality as far as reduced salination is concerned, is statistically insignificant and equal to 1.07 CYP per 0.1 ha of land. The statistical insignificance and small magnitude of the marginal WTP for improvements in groundwater quality derived from the hedonic model with selectivity correction implies that extraction behavior is myopic. That is, agricultural producers are not willing to pay a large amount for preserving groundwater quality today, because free-riding extracting agents might extract salt-free water tomorrow. This is of course an artifact of the non-existence of properly allocated property rights in a common-pool aquifer.

Moreover, another contributing factor towards a low marginal WTP for groundwater quality and existence of myopic extracting behavior, is that current farmers value the prospect of switching land-use to the more lucrative tourism industry (as compared to the agricultural sector). Tourism utilizes other existing sources of water (other than groundwater).

Estimation of the Marginal Value of Water and Risk Preferences in Agriculture

The agricultural production function for groundwater users is estimated econometrically and the marginal productivities of inputs as well as the effects of each of the inputs on risk are derived. Risk considerations are necessary in the understanding of the agricultural sector's use of water. Intelligent public policy should consider not only the marginal contribution of input use to the mean of output, but also the marginal reduction in the variance of output.

In the estimated production function, the sum of fertilizers, manure and pesticides (FMP) inputs, as well as water, had a significant and positive effect on expected profit. FMP and water exhibit decreasing marginal returns. Water and FMP and labor and FMP appear to be complimentary inputs. Water and FMP are risk increasing inputs (but at a decreasing rate). On the contrary labor appears to decrease the variance of profit, at an increasing rate (see Table **7.6**).

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 rather

Table 7.6 Estimated risk premiums and marginal productivity for inputs

Parameter	Water			Fertilizer			Labor		
Average risk premium (% of expected profit)	18			19			17		
Impact on variance of profit (other inputs constant)	+ve decreasing			+ve decreasing			−ve decreasing		
Marginal productivity	Citrus	Veg	Cereal	Citrus	Veg	Cereal	Citrus	Veg	Cereal
(By crop, CY£)	0.59	0.21	0.14	0.72	0.55	–	0.17	−0.32	0.25

than policies that do not differentiate among crops. In addition, for all crops specific production functions fertilizers and pesticides (either individually or jointly) exhibit higher marginal contributions than either water or labor.

Farmers exhibit moderate risk aversion and are willing to pay approximately one fifth of their expected profit to achieve the certainty equivalent: the profit received with certainty that leaves them as well off as with uncertain expected profit. No considerable heterogeneity of risk attitudes is observed in the population, so policies introduced to reallocate risk should be population rather than farmer specific. This is a reasonable result given that the agricultural region under consideration is small thus not allowing considerable variation to the accessibility of economic resources, services and information

Environmental Water Demand

As the standards of living increases in Cyprus the demand for water for recreational purpose increases. In recreation water has both a use value but also a non-use or existence value. Moreover, people who are willing to pay for this preservation might not be found inside the locality in which a wetland is located, i.e. the demand for these goods might be derived from people who care about it but live far away from it. In accordance with this premise research was undertaken aiming to derive the willingness to pay for environmental goods that are dependent upon freshwater resources, experienced locally but supplied regionally (Swanson et al. 2002).

The values were elicited using the hypothetical valuation methodology of Contingent Valuation Method (CVM), and the hypothetical market for existence value addressed in the context of the provision of water allocations for migratory species. The scenario used to create the hypothetical market was realistic: without regional cooperation for freshwater allocations, a migratory species that makes use of wetlands in both, Cyprus and the UK, the White-Headed Duck, is increasingly threatened with extinction. Those surveyed were asked to elicit preferences for the provision of water to endangered species under cooperative 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 (GBP10 per household per year). It is further demonstrated that there is an increased WTP (GBP10 + GBP5 per household per year) for the local allocation of water to species, if other states along the migratory route make similar allocations: the cooperative scenario. Moreover, three important points for the provision of environmental goods and, in this case, the allocation of water resources are also demonstrated: (1) wetland externalities are of a dual nature, both local and regional; (2) local WTP for a locally experienced public good may be enhanced through regional co-operation; (3) the regional optimal allocation of water to wetlands should take into account the sum of environmental benefits provided to the region, as perceived under the assumption of regional co-operation.

Balancing Values: Policy for Implementing Optimal Allocation

The optimal allocation of water resources in Cyprus should balance these various values of water within this catchment area. In Cyprus, the preferred method for implementing this optimal allocation was through the development of a uniform water pricing scheme. Hence water pricing for residential, agricultural and environmental uses was taken into consideration. This may be accomplished by means of determining the marginal social cost of water supply, and then charging each user of water this same price for the water. Then the resulting allocation would satisfy both of the principles for an optimal water allocation. The implementation of the optimal allocation of water in Cyprus can be implemented through design of the residential pricing of surface water, the agricultural pricing of groundwater and the evaluation of the marginal social cost of water.

Stage II: Policy Impact Analysis

The optimal allocation of water resources will take into consideration the relative values placed on water in the various sectors (residential, agricultural, environmental); however, there are other important factors which may or may not be taken into consideration under this allocation. These considerations include: equity (the impacts on lower income groups), risk (the impacts on variability on producer profitability) and hydrology (the impacts on conjoint users). The analysis of water resource management must include this supplemental analysis.

Equity: The Welfare Impacts of Water Pricing Policy

The household demand analysis described above shows that the current regionally heterogeneous increasing block pricing system in the island is progressive but introduces gross price distortions that are not justified either on efficiency or equity grounds. In terms of efficiency the current tariff system cannot be justified on the basis of the marginal social costs of water supply since the same water resource supplies all locations at very similar cost. Since large consumers of water pay a lower average price per cubic meter of water than users consuming smaller amounts of water, the current tariff system cannot be justified on equity grounds.

However, although a shift towards uniform marginal cost pricing will eliminate the deadweight loss of the current system, its benefits will be distributed in favor of the better off households. As such the policy could be considered to be inequitable. Overall, the analysis indicates that price can be an effective tool for residential water demand management in Cyprus, however, it may also lead to socially undesirable distributional effects on households.

Risk: The Impact of Water Pricing on Variability

The impact of water availability on the variance in producer profitability has been analyzed. This indicates how water affects the welfare of risk-averse agents. For example, we discovered that water has a positive but decreasing effect on the variance of profit. Other things remaining equal this means that although additional water increases the mean output/profit (positive marginal productivity), it increases the risk associated with output. The analysis shows that the population is risk averse, and therefore additional water may be welfare reducing. Similar arguments can be used for the other inputs.

Furthermore, one chief concern of reducing subsidies to agriculture is the impact that this may have upon employment. The production function has found no significant complementarity between labor and water inputs and as such this seems to indicate that the effect on employment will be due to any changes in output that occur, not from complementary reductions in labor use.

Hydrology: Conjoined Water Resources, Externalities and Market Failures

The logic behind treating the watershed as the management unit is that the interactions of the physical elements of hydrology and geo-hydrology and the human demand side can be coherently addressed and guide policy. Thus far the coupled nature of surface and groundwater and the wider impacts that the demands for one resource will impose upon the other has been largely ignored.

The policy impact analysis of Stage II should consider the conjoint use, and the impacts of one user on another. The impact of the allocation policy depends in part upon the nature of this coupling. One example is where groundwater use reduces surface water flows, that is, excessive groundwater pumping reduces surface water flows to downstream sectors, making optimal control of groundwater a potential solution to the water allocation problem. An alternative possibility is that groundwater use increases surface water availability via return flows, hence the timing of resource flows becomes important. Seasonal pricing could be used to ensure water availability to downstream users in line with their seasonal preferences. Of these possibilities, the former appears to describe the situation in the Kouris Catchment (Boronina et al. 2001). Thus optimal control of groundwater resources is likely to provide aggregate welfare improvements upstream, whilst effectively re-allocating surface water to the downstream residential sector and wetland areas.

Given the dependence of surface water flows on groundwater in the Kouris catchment the commonality of groundwater is wider than those users overlying the aquifer. Therefore the externalities associated with groundwater use will contain additional elements associated with the effects on surface water. The external effects of upstream groundwater use in this case may take two specific forms (1) appropriative externalities: groundwater users appropriate water from downstream users, preventing them from using water altogether and; (2) time Profile Externalities: Groundwater users determine the time profile of water flows for the downstream users e.g. through groundwater return flows.

The WTP for wetlands within the Kouris catchment has been demonstrated, making it likely that externalities related to Public Goods exist. WTP for Public goods has been demonstrated to exist both locally and regionally, beyond the confines of the watershed. The focus of policy should now be upon determining how these regional values can be transferred, to augment the local willingness to pay, in order to effect the centralized allocation of water resources to that end.

Legislative and Institutional Analysis

The proposed allocation of water needs to be backed up by legislative change. Cyprus water legislation is characterized by a piecemeal approach whereby the quality aspects of freshwater resources is dealt in several laws depending on the type and the use which is made of the resources concerned. Moreover, both water quality and quantity aspects are dealt with by several instruments, in particular with regards to groundwater. An integration process shall be required in the light of the provisions of the Water Framework Directive. The latter provides that all waters shall be addressed within the framework of River Basin Districts and individual river basins (the new water management unit) so as to ensure that water protection measures, including quality and quantity issues, are dealt with in a hydrologically coherent manner. As examined below, a good water status is to be achieved for all waters, which implies that the status of surface waters or groundwater shall be such as not to deteriorate the status of other water bodies.

In this context, the WFD provides for the drawing of River Basin Management Plans, which shall contain all measures that need to be implemented in a coordinated in each river basins so as to ensure protection for all waters. The WFD provides for the designation of a single competent authority in charge of the implementation of the environmental objectives of the directive in each River Basin District. The objective is to ensure consistency and coherence in decision-making and to guarantee that the integrated water management objective is achieved, in terms of co-ordinated protection of all waters, including surface waters, groundwater and protected areas.

Conclusion

The case study of the Kouris Watershed has described the implementation of the integrated watershed economics methodology described in the initial sections of this chapter. It has shown how the approach contributed to the development of policy recommendations for the Government of Cyprus. The study combined detailed hydrological models with micro-economic data on the water using sectors. The imbalance of water demand with the natural constraints of supply was addressed in the objective manner using the two stage process outlined above. In this case Stage I used a variety of economic valuation techniques: Hedonic analysis, Contingent Valuation, Travel Cost Approach, Mathematical Modeling and Distance Function (see Appendix), to assess the social value of water in the different sectors. This allowed the determination of the efficient pricing strategy for allocating between water demands to maximize social welfare. Stage II analyzed the impact of the proposed allocation policy in order to address issues of equity and sustainability.

Appendix

Terminology

- **Marginal Value**: is a term used in economics to refer to the change in economic value associated with a unit change in an economic choice variable. 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**: Measures the responsiveness of demand to price changes. Characterizes the demand function and tells the policy maker the extent to which prices must change to cause demand to fall to a particular, e.g. efficient, sustainable, level.
- **Income Elasticity**: Measures the extent to which the demand for water varies with income. 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 can be used to estimate welfare changes resulting from policies.
- **Willingness to Pay**: Estimates the strength of demand for water as an environmental good. This determines in part the efficient environmental allocation of water.

Valuation Methods

Hedonic analysis: is most commonly applied to variations in housing prices that reflect the value of local environmental attributes. Thus, property prices will reflect the value of a set of characteristics, including environmental characteristics that people consider important when purchasing a property.
Contingent Valuation: is a non-market-based technique that elicits information concerning environmental preferences from individuals through the use of surveys, questionnaires, and interviews. This method enables the market for a public good to be simulated and described and then asks individuals what they would be willing to pay for that good or what they would be willing to accept as compensation if this good were lost or unavailable.
Travel Cost Approach: the basic premise of this method is that the time and the cost expenses that people incur to visit a site represent the price travelers assign to the site and its attributes. Thus, the number of trips realized at different travel cost can provide a robust index of individual's Willingness to Pay for access to the site.
Distance Function: is used to estimate the economic value of ecosystem products or services that contribute to the production of commercially marketed goods. It is applied in cases where the products or services of an ecosystem are used, along with other inputs, to produce a marketed good.

[AU2]

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