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Abstract	<p>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.</p>	
Keywords (separated by '-')	Watershed economics approach - Economic valuation techniques - Balancing demands - Social equity - Kouris watershed	

Chapter 7 1

The Economics of Water Resource Allocation: 2

Valuation Methods and Policy Implications 3

Ben Groom and Phoebe Koundouri 4

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Keywords Watershed economics approach • Economic valuation techniques 17
• Balancing demands • Social equity • Kouris watershed 18

Introduction 19

How is it possible to allocate water in Cyprus between its many competing uses, all 20
of which depend on water for their existence? Clearly water resources are necessities 21
for many of the most important goals of every society. Firstly, water is a necessity 22

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23 for human existence. The absence of clean drinking water and sanitation leads to
24 health problems, whilst the lack of access to/property rights for water resources per
25 se is a significant dimension of poverty. Water is also an important input to economic
26 activities and can be seen as both a production and consumption good (Young 1996).
27 Furthermore water is a public good contributing to recreation, amenity and general
28 environmental and watershed values as an input to ecosystems and habitats. How
29 can it be possible to balance such crucially important but competing uses?

30 The fact is that a balancing of these uses must be accomplished, and the mecha-
31 nism for doing so must be carefully constructed. The existing overlay of complex
32 hydrological, socio-economic and property rights/legal environments (in many if not
33 most jurisdictions) predisposes water resources to open access appropriation within
34 the watershed, and the consequence of negative environmental and economic exter-
35 nalities (e.g. the degradation of wetlands and coastal fisheries, depletion of aquifers,
36 and loss of watershed services) (FAO 1987; Winpenny 1991). In short, the combination
37 of the *arbitrariness of the prevailing property rights* structure for water resources in
38 most jurisdictions and the *failure of markets* to capture the value of many watershed
39 services necessarily imply that the prevailing distribution of water within most societies
40 is not likely to be the most desirable one (e.g. Winpenny 1994).

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

49 In what follows a 'watershed economics approach' that could be applied in
50 Cyprus is proposed which is composed of two important stages. In Stage I economic
51 valuation techniques are used to establish the economic value of the competing
52 demands for surface and groundwater, incorporating where necessary an analysis
53 of water quality. The valuation exercise allows the objective balancing of demands
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58 allocation and scarcity since it determines the hydrological links between competing
59 users and thus the impacts of one user upon another. The methodology is encapsu-
60 lated by a case study of the Kouris watershed in Cyprus.

61 **Balancing the Demands for Water Resources: The Methodology**

62 The methodology we propose for application to the underlying problem of watershed
63 management is based on (1) the identification of the appropriate unit for manage-
64 ment; (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.

103 ***Stage I of Methodology: Objective Approach***
104 ***to Balancing Water Demands***

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

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

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

128 ***Stage II of Methodology: Policy Impact Analysis***

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

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

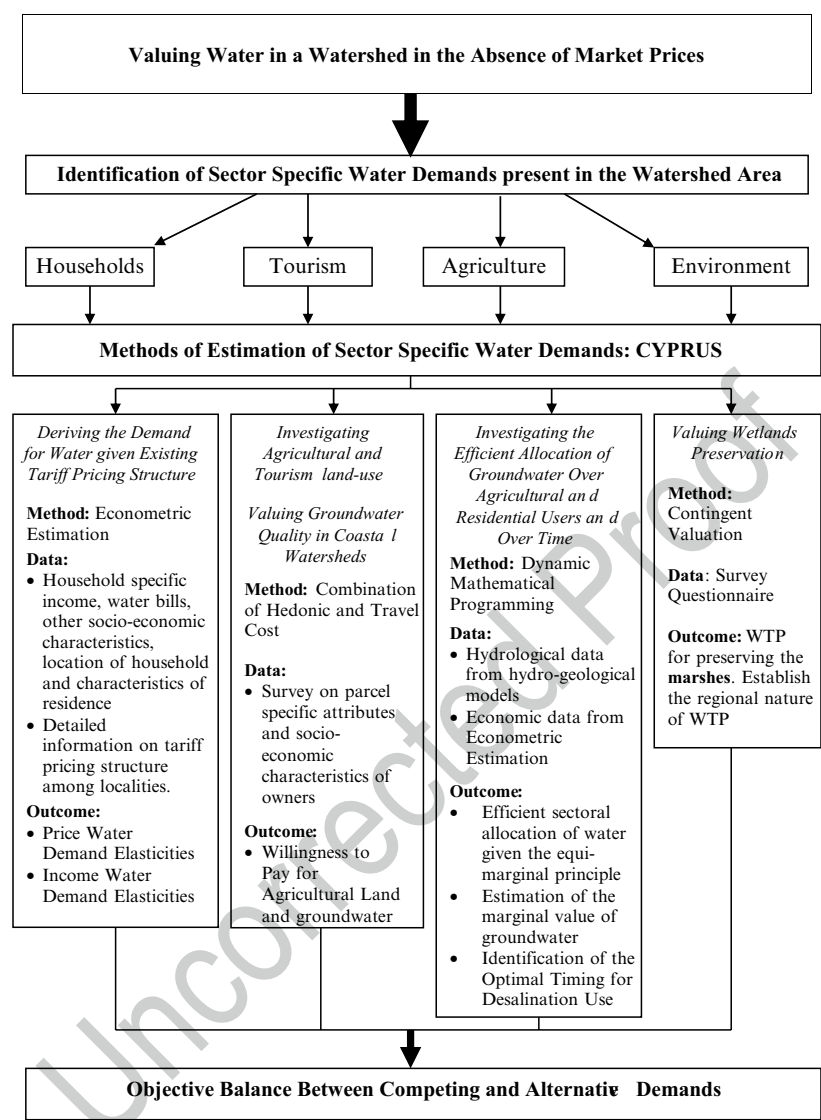


Fig. 7.1 The methodology for water demand valuation in a watershed area: examples from the Kouris watershed in Cyprus

frequently extends beyond the watershed. Global and regional environmental goods 143
 for which existence, bequest and option values are held provide an example of this. 144
 Furthermore, where water scarcity is extreme, demands for water outside the watershed 145
 may induce investments in inter-basin transfers. 146

Finally, as one of the main obstacles to water re-allocations a review of the legislative 147
 and institutional environment required to effect the desired allocation may be required. 148

149 **Case Study: Kouris Watershed in Cyprus**

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

156 ***Overview of Human and Physical Aspects: Hydrology*** 157 ***and Water Supply***

158 Cyprus is an arid island state situated in the north-eastern Mediterranean in which
159 renewable freshwater resources are highly constrained. The hydrological cycle of Cyprus
160 is characterized by spatial and temporal scarcity in water quality and quantity. For more
161 details on the hydrological conditions in Cyprus, see Chapters 2, 3 and 8 of this volume.

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

167 The most significant investments, as indicated in previous chapter of the book
168 (mainly Chapter 2) have been those contributing to the Southern Conveyor Project
169 (SCP). This scheme forms an interconnected water supply system which allows the
170 transfer of water resources throughout the southern part of the island, and also to
171 and from the capital Nicosia. Currently all aquifers are exploited beyond their safe
172 yield, with the excess of use over natural recharge estimated to be 40 Mm³/a.

173 ***Sectoral Water Consumption***

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

178 There is a distinct seasonality to the demands for water from both of these water
179 consuming sectors. Urban demands are clearly higher in the tourist season, whilst
180 the demands for agriculture also vary according to the growing season. Economic
181 growth has averaged 6% over the past 15 years, driven largely by up to 10%
182 annual growth in the tourist sector. There has also been nominal economic growth
183 in the industrial sector. Under current Government plans, the irrigation sector will be
184 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) t1.1

Water source	Average quantity (Mm ³ /a)	Description	
Surface Water	130–150	Diverted to storage dams; subject to evaporation	t1.4
	150	Diverted direct from rivers for irrigation	t1.5
Groundwater	270	Pumped or extracted from springs	t1.6
Desalination	6.5	Supplies residential areas: capacity to increase	t1.7
Recycling	4	Planned to be increased to 13 Mm ³ /a	t1.8

Table 7.2 Water consumption in the major water schemes in Cyprus, MCM/a (1994) t2.1

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	t2.3
Khrysokhou system	0.4	6.3	6.7	t2.4
Other	8.1	84.5	92.6	t2.5
Total	55.4	160.0	215.4	t2.6

Adapted from World Bank (1996) t2.7

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 193

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

t3.1 **Table 7.3** Water balance for the Southern Conveyor Project

t3.2	Demand and supply		1995	2000
t3.3	Water Supply	Surface water	61.8	61.8
t3.4		Groundwater	28.0	28.0
t3.5		Diversions	16.3	16.3
t3.6		Desalination	–	6.5
t3.7		Reuse	1.0	7.0
t3.8	Total supply ^a		101.1	109.6
t3.9	Water Demand	Urban	42.7	48.9
t3.10		Irrigation	45.9	61.2
t3.11	Total demand		88.6	110.1
t3.12	Water balance		12.5	–0.5
t3.13	^a Net of evaporation: 6 MCM/a. Source World Bank (1996)			

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

208 The SCP caters for 40% of the aggregate demand; 80% of all urban demand and
 209 25% of all agricultural demand. Clearly, the average water balance for the SCP
 210 scheme is negative based on the surface water flows witnessed over the 25 year
 211 period and the observed water demands. It is the deficit of surface water flow where
 212 the main shortfall occurs. Given the yearly fluctuations in precipitation and the
 213 resultant surface flow, the picture of scarcity and the severity of the deficit varies
 214 from year to year. With demands at 2,000 levels, the pattern of surface water flows
 215 observed over the past 25 year period would lead to several years of water deficit,
 216 many of which would be severe. Indeed the droughts of 1989–1991 and 1995–1999
 217 illustrate the immediacy of the water balance deficits and the potentially unsustain-
 218 able path of water resources management under the current system.

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

229 With regards to institutional and legislative background, as well as the property
 230 rights to water resources, as discussed in detail in Section [Stage 1: The Evaluation
 231 of Water Demand in Cyprus](#) (also commented upon in all chapters of this book), the
 232 current property rights are in part based on the riparian principle and the ‘rule of
 233 capture’ (first in time first in right) and the resulting pattern of demand is uncoor-
 234 dinated. Although the Government has the responsibility for monitoring and
 235 protecting water resources, this responsibility is divided between many institutions
 236 resulting in a fragmented regulatory framework.

The Need for a Policy Change

237

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

258

Background to the Kouris Watershed

259

The Kouris watershed covers 300 km² 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
t4.1		
t4.2		
t4.3	1. Rainfall data	Precipitation for the period 1970–1995 was established in annual and 5-year moving average terms for specific meteorological stations
t4.4	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
t4.5	3. Correlation of rainfall with river discharge	
t4.6	4. Evapo-transpiration	Measurements of evapo-transpiration at different altitudes were taken using evaporation pans
t4.7	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
t4.8		
t4.9	6. Aquifer properties	The description of the aquifer was based on pumping tests and lineament analysis. From this transmissivity was estimated
t4.10	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
t4.11		
t4.12	2. Meteorological and gaging stations	The location and density within that location of meteorological and gaging stations was mapped.
t4.13	3. Geology and springs	The location and flow of permanent springs was mapped onto the Geological map of the catchment
t4.14	4. Transmissivity and piezometry	Maps were developed describing the piezometry and the transmissivity of the aquifers in the catchment
t4.15	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
t4.16	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
t4.17		
t4.18		
t4.19		
t4.20		
t4.21		
t4.22		
t4.23		
t4.24		
t4.25		
t4.26		
t4.27		
t4.28		
t4.29		

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

314 Nordin’s difference variable (in the case of multiple tariffs, this variable is the
 315 difference between the total bill and what the users would have paid if all units were
 316 charged at the marginal price) in empirical models of residential demand.

317 We estimate a model consistent with fundamental principles of the economic
 318 theory of consumer behavior (Hadjispirou et al. 2002). We choose the Quadratic
 319 Almost Ideal Demand System (QUAIDS) model for the following reasons. First,
 320 we estimate demand for water using individual household data for which lower
 321 rank demand systems are to be inadequate to capture the non-linear income effects
 322 pertaining to these data. Second, we need a demand system that satisfies integrability
 323 (the ability to recover the parameters of the indirect utility function from empirical
 324 demand analysis) because we plan to analyze the welfare implications of alternative
 325 water pricing policies on empirical grounds. We consider the ability to evaluate the
 326 welfare implications of alternative water pricing policies particularly important,
 327 given the significance attached to equity and the strong political objections to water
 328 price reform in Cyprus based on political economy arguments.

329 The theoretical model described above is applied to individual household data,
 330 contained in the Family Expenditure Survey (FES) of Cyprus 1996/1997. This
 331 allows estimation of the price and income elasticities of residential demand for
 332 water in Cyprus, the marginal value of water in the residential sector and evaluates
 333 the welfare effects associated with changes in the water pricing system. Empirical
 334 results show that the current water pricing system is progressive but inefficient in
 335 the sense that it introduces gross price distortions resulting in deadweight loss. The
 336 regional difference, in particular, introduces a substantial price heterogeneity that
 337 cannot be justified on the basis of efficiency or equity criteria. It cannot be justified
 338 on efficiency grounds because it is difficult to imagine that in a small island like
 339 Cyprus such large regional differences in price can reflect difference in supply
 340 costs. The regional price heterogeneity cannot also be justified on equity grounds
 341 because we found that users consuming much smaller amounts of water.

342 Moreover, the empirical analysis suggests that the marginal value of water in the
 343 residential sector is CYP 0.45/m³. The price elasticity of demand for water ranges
 344 between – four for households in the lowest and – eight for households in the highest
 345 10% of income distribution (see Table 7.5). This means that the demand curve for
 346 water is downward sloping and for high-income water users, highly responsive to
 347 price changes. This suggests a strong role for price as a demand management tool.
 348 As indicated by the estimated elasticities, water is complementary to water intensive
 349 luxury goods such as swimming pools and gardens with lawns.

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

t5.1 **Table 7.5** Estimated household price and budget elasticities of demand for water

	Income group percentiles					
t5.2 Elasticity	Bottom 10%	11–25%	26–50%	51–75%	76–90%	Top 10%
t5.3 Budget	0.25	0.22	0.23	0.30	0.35	0.48
t5.4 Price	-0.79	-0.69	-0.60	-0.56	-0.50	-0.39

t5.5 Koundouri et al (2000a)

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 359

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.

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

403 Lastly, an alternative methodology, the distance function approach, is employed to
404 estimate the scarcity rents of the Kiti groundwater using more applicable behavioral
405 assumptions for agriculturists (Koundouri and Xepapadeas 2004). The first virtue of
406 distance functions is that they do not necessarily require price data to compute the
407 parameters; only quantity data is needed. Secondly, distance functions do not impose
408 any behavioral hypothesis (such as profit maximization or cost minimization). That
409 is, they allow production units to operate below the production frontier (i.e. to be
410 inefficient) and they also allow derivation of firm-specific inefficiencies. Thirdly,
411 duality results between distance functions and the more conventional cost, profit and
412 revenue functions provide flexibility for empirical applications.

413 Given that technical change is assumed to be constant in the estimated model over the
414 relevant time period, these results allow the conclusion that the managers of the agricul-
415 tural firms in the sample under consideration, learn from their previous experience in the
416 production process and as a result their technical inefficiency effects change in a persist-
417 ent pattern over time. The reported substantial increases in the technical efficiency of
418 agricultural firms can be attributed to the major restructuring of the agricultural sector
419 that took place in the last decade in an attempt to harmonize the Cypriot agricultural
420 policies with those of the European Union, in the light of Cyprus accession in the EU.
421 Alternatively, increases may indicate the existence of technological progress in the agri-
422 cultural sector under consideration, which is not accounted for in our empirical model.
423 These are the first estimates of the efficiency of the Cypriot agricultural sector and as a
424 result there is no scope for comparison at the present. The central result of this empirical
425 application, however, is that estimated technical firm-specific inefficiencies present in
426 production technologies of agricultural, suggest that cost minimization is not the relevant
427 behavior objective in Cyprus irrigated agriculture. This result provides support for the
428 use of the distance function approach to derive resource scarcity rents.

429 The unit scarcity rent of in situ groundwater estimated by the distance function is
430 approximately equal to zero (0.0097 CYP/m^3) under the myopic common property.
431 This is approximately 20 times less than the value under optimal control. This compar-
432 ison indicates that agricultural producers in the region are not willing to pay the full
433 social cost of their extraction. This implies that under common property, externalities
434 arise, as current users of the resource are willing to pay only the private cost of their
435 resource extraction, and as a result the resource's scarcity value goes completely unrec-
436 ognized. This pattern of behavior is consistent with perfect myopic resource extraction,
437 which arises because of the absence of properly allocated property rights in groundwa-
438 ter, and is consistent with the results on WTP for groundwater quality.

Estimating the Scarcity Value of Groundwater: Quality

439

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

462

463

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 complementary 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

t6.1 **Table 7.6** Estimated risk premiums and marginal productivity for inputs

t6.2	Parameter	Water			Fertilizer			Labor		
t6.3	Average risk premium	18			19			17		
t6.4	(% of expected									
t6.5	profit)									
t6.6	Impact on variance of	+ve decreasing			+ve decreasing			-ve decreasing		
t6.7	profit (other inputs									
t6.8	constant)									
t6.9	Marginal productivity	Citrus	Veg	Cereal	Citrus	Veg	Cereal	Citrus	Veg	Cereal
t6.10	(By crop, CY£)	0.59	0.21	0.14	0.72	0.55	-	0.17	-0.32	0.25

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

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

490 ***Environmental Water Demand***

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

499 The values were elicited using the hypothetical valuation methodology of
 500 Contingent Valuation Method (CVM), and the hypothetical market for existence
 501 value addressed in the context of the provision of water allocations for migratory
 502 species. The scenario used to create the hypothetical market was realistic: without
 503 regional cooperation for freshwater allocations, a migratory species that makes use
 504 of wetlands in both, Cyprus and the UK, the White-Headed Duck, is increasingly
 505 threatened with extinction. Those surveyed were asked to elicit preferences for the
 506 provision of water to endangered species under cooperative and non-cooperative
 507 funding scenarios. Econometric analysis of the survey responses demonstrated that
 508 there exists a positive WTP for the provision of local water to the endangered
 509 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 519

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 531

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 539

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

544 basis of the marginal social costs of water supply since the same water resource
545 supplies all locations at very similar cost. Since large consumers of water pay a
546 lower average price per cubic meter of water than users consuming smaller amounts
547 of water, the current tariff system cannot be justified on equity grounds.

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

554 ***Risk: The Impact of Water Pricing on Variability***

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

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

568 ***Hydrology: Conjoined Water Resources, Externalities*** 569 ***and Market Failures***

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

575 The policy impact analysis of Stage II should consider the conjoint use, and the
576 impacts of one user on another. The impact of the allocation policy depends in part
577 upon the nature of this coupling. One example is where groundwater use reduces
578 surface water flows, that is, excessive groundwater pumping reduces surface water
579 flows to downstream sectors, making optimal control of groundwater a potential solu-
580 tion to the water allocation problem. An alternative possibility is that groundwater
581 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) appropriate 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

623 and to guarantee that the integrated water management objective is achieved, in
624 terms of co-ordinated protection of all waters, including surface waters, groundwa-
625 ter and protected areas.

626 Conclusion

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

641 Appendix

642 Terminology

- 643 • **Marginal Value:** is a term used in economics to refer to the change in economic
644 value associated with a unit change in an economic choice variable. The efficient
645 balance of demands from a given source is found where the marginal value
646 (benefit) of water is equated across users. In any given context efficiency is
647 achieved where the marginal value of water is equated to marginal social cost.
- 648 • **Price Elasticity:** Measures the responsiveness of demand to price changes.
649 Characterizes the demand function and tells the policy maker the extent to which
650 prices must change to cause demand to fall to a particular, e.g. efficient, sustain-
651 able, level.
- 652 • **Income Elasticity:** Measures the extent to which the demand for water varies with
653 income. Tells the policy maker whether water is a necessity or a luxury good and
654 provides one way in which to assess the fairness of pricing policies. In combination
655 with PED can be used to estimate welfare changes resulting from policies.
- 656 • **Willingness to Pay:** Estimates the strength of demand for water as an environmental
657 good. This determines in part the efficient environmental allocation of water.

Valuation Methods

658

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.

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Author Queries

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Queries	Details Required	Author's Response
AU1	'Koundouri et al (2000a)' is cited in text but not given in the reference list. Please provide details in the list or delete the citation from the text.	
AU2	Following references are not cited in text:	
	Department of Statistics and Research Ministry of Finance, Republic of Cyprus, Demographic Report (1997), Family Expenditure Survey 1996/97.	

Uncorrected Proof