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Assessing the Economic Viability of Alternative Water Resources in Water-Scarce Regions

Combining Economic Valuation, Cost-Benefit Analysis and Discounting

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ABSTRACT

This paper demonstrates a comprehensive methodology for assessing the viability of an environmental management plan that has long-run economic and ecological impacts. The case study under consideration is the implementation of a water resource management plan in a water-scarce region of the world, namely Cyprus. Specifically, this plan proposes to replenish a depleting aquifer with treated wastewater. The proposed methodology first identifies the key stakeholder groups (farmers and the general public) who are hypothesized to derive economic values (benefits) from implementation of this plan, and then uses stated-preference methods to capture the total economic value of these benefits. Benefits are aggregated over the relevant populations of these stakeholder groups and weighed against the total costs of implementing the plan in a long-run cost-benefit analysis (CBA). An econometrically estimated time-declining trajectory of discount rates is used for the CBA in order to assess the long-run sustainability of the plan. The results reveal that the net benefit trajectory estimated with the time-declining discount rate takes one and a half to three times as long to come to a plateau compared to the constant discount rates of 3.5 and 6 percent, emphasizing the importance of using declining discount rates and capturing the entirety of the benefits generated by such plans. This methodology is particularly recommended for providing much needed information to support the implementation of the EU Water Framework Directive, which advocates the use of CBA with consideration of the notion of sustainability for achieving the “good water status” for all European waters.

Keywords: Aquifer Recharge, Treated Wastewater, Total Economic Value, Choice Experiment, Long-run Cost Benefit Analysis, Declining Discounting

1. INTRODUCTION

The estimation of all values generated by environmental goods and services for the cost-benefit analysis (CBA) of policies and projects has long been advocated (Pearce 1993). The need for this overall figure, termed the total economic value (TEV), is based on the argument that environmental goods and services generate not only use values such as direct, indirect and option use values, but also non-use values, such as existence, bequest and altruistic values (Freeman 2003). For comprehensive CBA of projects and policies that involve environmental goods and services, the TEV should be captured, i.e., the economic benefits generated by environmental goods and services should be quantified in monetary units, and weighed against the costs of conserving or providing such goods and services.

The "sustainability" context pertaining to long-run and inter-generational equity issues requires appropriate discounting of the costs and benefits of conserving or providing environmental goods and services. Recent reports in the discounting literature have proposed the use of an econometrically estimated time-declining trajectory of discount rates for better assessing the sustainability of policies/projects that propose to conserve or provide such environmental goods and services (Gollier et al. 2008).

The aim of this paper is to document a comprehensive methodology for assessing the viability of an environmental management plan that has long-run economic and ecological impacts. The plan under consideration is an aquifer management plan to replenish a depleting aquifer with treated wastewater in a water-scarce region of the world, namely Cyprus.[1] It is expected that the results of this study will provide decision makers with recommendations that may help the sustainable management of Cyprus' scarce water resources and the timely implementation of the European Union's (EU) Water Framework Directive (WFD (2000/60/EC)).

To this end, one of the main aquifers in Cyprus, the Akrotiri aquifer, is herein used as a case study. Based on a comprehensive literature review, focus group discussions (FGDs), and informal interviews with local experts, policy makers, farmers, and members of the general public, we identified local farmers and the residents of the nearby city of Limassol as the main stakeholders that would benefit from such a plan. Farmers located in the area derive both direct use and option values from the aquifer, as they irrigate their farms with water from the aquifer. Limassol residents, on the other hand, derive indirect use values through the consumption of locally produced vegetables, as well as non-use values from the ecological status of the local environment and the employment of locals in agriculture, both of which are supported by the aquifer.

In our analysis, two distinct choice experiments (CEs) are performed on randomly selected members of these two key stakeholder groups, allowing us to estimate the use and non-use economic benefits that may arise as a result of the proposed aquifer management plan. These estimated benefits are aggregated over the relevant populations and weighed against the costs of providing such an intervention. Since the costs and benefits of this plan are expected to have impacts well into the future, a long-run CBA is conducted under different discount rate schemes (constant and declining discount rates). The results of this long-run CBA reveal that the net benefit generated by the aquifer management plan is positive and significant well into the future, regardless of the utilized discount rate scheme. However, the net benefit trajectory estimated with the declining discount rate is higher than those estimated with constant discount rates. Moreover, the net benefit trajectory under the declining discount rate trajectory takes one and half to three times as long to come to a plateau compared to the constant discount rates of 3.5 and 6%. Our results, therefore, have implications for the use of declining discount rates for evaluating projects or policies with long-term ecological and economic impacts in general, and in terms of informing efficient water resource management in Cyprus in particular. The methodology developed herein will especially benefit EU member states that are obligated to implement the WFD, since the Directive specifically calls

[1] Please note that throughout the paper, "Cyprus" refers to the Greek Cypriot area of the island, which is controlled by the government of Cyprus.

for the application of long-run CBA and consideration of the sustainability criterion when developing and adopting measures aimed at achieving good water status for European water resources.

The rest of the paper unfolds as follows: The next section describes the case study. Section 3 introduces the CE approach, the design and implementation of the two experiments, and their results. Section 4 reports the results of the CBA and discusses the use of different discount rates for public projects and policies having long-run impacts. The final section concludes the paper and draws policy implications.

2. THE AKROTIRI AQUIFER CASE STUDY

Efficient management of its scarce water resources has historically been one of the most important resource challenges facing Cyprus (Koundouri, forthcoming). As a member of the EU, Cyprus is obligated to adopt and implement the WFD, which aims to achieve "good [ecological, chemical and physical] status" for all European waters by 2015 (WFD (2000/60/EC)). Article 11(3)(c) of the Directive emphasizes the need to find sustainable solutions, and specifies that measures to promote efficient and sustainable water use must be introduced in order to safeguard environmental objectives. Furthermore, the Directive calls for economic estimation of the costs and benefits of various measures (both economic and technological), and the use of a thorough CBA to determine the most efficient, effective and equitable means of achieving good water status. In Cyprus, the key elements of the WFD have been adapted into national legislation through the "Water Protection and Management Law of 2004," and (as is the case in several other member states) implementation of the Directive is currently underway (Koundouri, forthcoming).

The case study presented herein is that of the Akrotiri aquifer, which is a common-pool resource and the third largest aquifer in Cyprus. This coastal aquifer is extremely important for the local economy and ecological stability. Extending over 42 km,2 the Akrotiri aquifer not only provides local farmers with irrigation water, it also supports the largest inland aquatic system in the country and plays host to unique ecological habitats and biodiversity riches (Birol et al. 2008). The Akrotiri wetland, a product of aquifer runoff, is recognized as a wetland of national and international importance by the Ramsar Treaty (site no: 1375), as an important bird area by Birdlife International, and as a special protected area by the Barcelona Convention (Kailis 2005). The aquifer is replenished with runoff from the Kouris River, releases from the Kouris River dam, rainfall, and agricultural return flows (Mazi et al. 2004).

The aquifer is presently facing serious water quality and quantity problems, which are expected to have significant adverse effects on the livelihoods of the local farmers as well as on the area's ecological conditions in the not too distant future. Since the construction of the Kouris River dam, the aquifer's water inflow has decreased significantly, resulting in a lower water table (Mazi et al. 2004). This has lead to the intrusion of saltwater as the aquifer attempts to maintain its hydrological balance. Water quality in the aquifer has further deteriorated due to the intensive use of fertilizers and pesticides in the area's agricultural production. The quantity of water in the aquifer has been adversely affected by uncontrolled and excessive pumping, which arises through the lack of clearly defined property rights, i.e., the open access nature of the aquifer. In combination with climate change-associated decreases in precipitation, this aquifer depletion is expected to cause desertification in the future, with the associated deterioration of the area's ecological conditions.

In order to mitigate the adverse effects of reduced water availability and deteriorating water quality in this aquifer, its replenishment with treated wastewater from Limassol and nearby villages has been proposed. Among the [proposed technologies aimed at alleviating water scarcity, wastewater treatment and reuse is promising, especially in water-scarce regions (Fetter et al 1974; Paling 1987; Bouwer 1992; Barnett et al. 2000; Scott et al. 2004). Large-scale wastewater treatment was initiated in the Limassol prefecture with the construction of a treatment plant in 1995. The objective of this initiative was to provide a safe and reliable system for wastewater disposal and to improve ecological conditions and overall water-resource management (Papaiacovou 2001). To date, the wastewater treated in this plant has been discharged into the Mediterranean Sea.

Recently, the government has begun considering a plan to recharge the rapidly depleting Akrotiri aquifer with treated wastewater, in order to reduce the effects of seawater intrusion and ensure the sustainability of the current water quality and quantity levels in the aquifer. The case study presented in this paper aims to inform decision makers by presenting a thorough assessment of the economic viability and sustainability of such a plan.

3. VALUATION OF THE BENEFITS OF TREATED WASTEWATER

Choice Experiment Design and Survey Development

Focus group discussions (FGDs) with local farmers and members of the public, expert consultations with water policy makers and scientists who have been working in the area (hydrologists, ecologists and agronomists), and a thorough review of the literature on the use of wastewater for irrigation in general and water-resource management in Cyprus in particular revealed the existence of two main stakeholder groups that are projected to derive significant economic benefits from the Akrotiri aquifer. The first is comprised of the local farmers, who use the aquifer as an irrigation source. This stakeholder group derives mainly direct use and option values from the aquifer. The second group is the public located in the nearby city of Limassol. This stakeholder group derives indirect use values through the consumption of locally produced food, as well as non-use values from conservation of the local environment and agricultural employment, both of which are supported by the aquifer. Here, two distinct choice experiments (CEs) are carried out in order to capture the different components of economic value accrued by these two stakeholder groups.

The three key attributes of the aquifer management plan and the levels they might take with and without the aquifer's replenishment with treated wastewater were identified through consultations with hydrologists, ecologists, agronomists, and local water-policy makers, as well as FGDs with local farmers and Limassol residents. Since a simple CE design was envisaged for both stakeholder CEs, only the three most important aquifer attributes were included, along with the mandatory monetary attribute. The selected attributes and the levels they encompass for each of the CEs are shown in Table 1.

Table 1. Attributes and levels used in the two choice experiments (CEs)

Attribute	Definition	Attribute levels
	Farmer CE	
Water quality	Quality of water in the aquifer	Current water quality vs. <u>Lower water quality *</u>
Water quantity	Quantity of water in the aquifer	Current water quantity vs. <u>Lower water quantity</u>
Agricultural employment	Number of farmers employed in the area	<u>1275</u>, 1380, 1455, or 1500
Price	Percentage increase in the price per m^3 of water pumped from the aquifer by the farmer	<u>Current price vs.</u> 50% increase, 25% increase, or 10% increase in price
	Resident CE	
Water quality	Quality of water in the aquifer	Current water quality vs. <u>Lower water quality</u>
Agricultural employment	Number of farmers employed in the area	<u>1275</u>, 1380, 1455, or 1500

Table 1. (Continued)

Attribute	Definition	Attribute levels
	Resident CE	
Ecological conditions	Ecological conditions in the area, including habitat health and biodiversity conservation	Current ecological conditions vs. desertification
Price	Percentage increase in the price per m^3 of water used by the household	Current price vs. 50% increase, 25% increase, or 10% increase in price

*Underlined levels depict the status quo situation.

In the farmer CE, water quality and quantity attributes are specified to have two levels: current (medium) level and low level. Water quality is associated with the quality of treated wastewater used in replenishment and the subsequent water quality in the aquifer. Our expert consultants believe that the water quality in the aquifer can be maintained indefinitely at its current, medium-quality level if high-quality treated wastewater is used for its replenishment. If, however, no action is taken to replenish the aquifer, or if untreated/low-quality treated wastewater is used for replenishment, then in the medium-run (five years), the quality of water is expected to deteriorate to a low level due to increasing salinity in the former case and unhygienic irrigation water quality in the latter case. This situation will continue through the long run (10 years). Under the situation of low water quality, farmers would be unable to continue cultivating their current crops (mainly vegetables); they would need to switch to tree crops (if low-quality treated wastewater is used for replenishment) or crops that are resilient to saline water (if no action is taken to replenish the aquifer).

Water quantity, which is defined in terms of the availability of water for irrigation, also takes two levels: current (medium) level or low level. If the extraction of water continues at the current rate and no plans are implemented to replenish the aquifer with treated wastewater, then the water quantity in the aquifer is expected to decrease to a low level, and remain at that level in the long run. Under the condition of low water levels in the aquifer, the farmers' pumping costs are projected to increase by 1.5- to 2-fold their current levels.

The employment attribute refers to the number of part-time and full-time farmers employed in the area. At present, there are approximately 1500 local farmers who benefit from the aquifer. If the current conditions of uncontrolled water extraction prevail, it is expected that agricultural employment in the area will decrease by 15 percent (to 1275 farmers) in the medium- to long-run, and remain at that level in the future. If, however, the plan to replenish the aquifer with treated wastewater is implemented, then employment in agriculture might remain constant at 1500 farmers, or it might decrease by up to 15 percent depending on the government's agricultural policies and out-migration.

For our analysis, the monetary attribute, which is necessary for estimating welfare changes, is defined as the price per m3 of water extracted from the aquifer. The price of water under the aquifer management plan is expressed as a percentage increase of the current average price paid by each farmer. Under the proposed aquifer management plan, the price of water currently paid by the farmers could remain the same, or it could increase by 50, 25 or 10 percent. We collected information on the farmers' current costs per m3 of water, enabling us to convert the percentage levels to monetary levels for each farmer.

The selected attributes for the resident CE implemented in Limassol include water quality, ecological conditions, employment in agriculture, and water prices (Table 1). The employment in agriculture attribute is defined as described above. This attribute is included in the resident CE to test the hypothesis that the public may derive economic benefits not only from ecological factors related to the aquifer, but also from social and economic factors (Portney 1994). Several CE studies have included social and economic factors, such as the number of people employed or living in the countryside, in order to capture the economic benefits that the wider public gains from the provision of such factors (e.g., Bennett et al. 2004; Othman et al. 2004; Colombo et al. 2005; Bergmann et al. 2006; Birol et al. 2006).

The water quality attribute is defined as impacting the type of crops cultivated by local farmers, as described for the farmer survey. This attribute is also expected to have indirect economic impacts on the residents in terms of the availability and diversity of locally produced vegetables.

The ecological condition attribute refers to the possible effects of the desertification that may take place in the region due to decreased water availability. The habitats and biodiversity riches currently supported by the Akrotiri aquifer through the Akrotiri wetland are expected to be lost as a result of desertification. If the aquifer is replenished with treated wastewater, then the ecological conditions in the wetland would be expected to remain at their current conditions. On the other hand, if replenishment plans are not implemented, the aquifer (and hence the wetland) will be drained as a result of excessive extraction, and the local ecological conditions will deteriorate.

The utilized payment vehicle is the percentage increase in the price per m3 of water used by a household. The price can remain at the current level, or it may increase by 50, 25, or 10 percent. As in the farmer survey, information on residents' current expenditures per m3 of water was collected, allowing us to convert these percentage levels to monetary levels for each household.

The number of attributes and the attribute levels selected for these two CEs reflect a balance of efficiency, a resemblance to reality, and the enhancement of each attribute's variability (Kontoleon 2003). Of the four attributes used in each experiment, two may take four levels and two are binary. A large number of unique aquifer management plan descriptions (combinations of attributes) can be constructed from the utilized attributes and levels. However, in this design, an orthogonalization procedure is used to recover only the main effects, yielding 16 pair-wise comparisons of aquifer management plan profiles for each CE. Although our exclusion of interaction effects may introduce bias into the main effects estimations, it has been shown that main effects usually account for more than 80 percent of the explained variance in a model (Louviere et al. 2000).

The optimal number of choice sets presented to each individual varies according to the difficulty of the choice tasks, the conditions under which the experiment is conducted, and the incentives provided to the respondents. Any number of choice sets between four and 16 is generally considered to be efficient (Louviere et al. 2000). Accordingly, the 16 pair-wise aquifer management-plan comparisons were randomly blocked into two different versions, each with eight choice sets. Each respondent was presented with eight choice sets, each with two aquifer management plans and an option to select neither. If the respondents chose neither plan, then the "business as usual" scenario was defined as the situation that will prevail within the next decade if no interventions are implemented. Examples of the choice sets presented to the farmers and residents are presented in Figures 1 and 2.

Figure 1. Example of a choice set presented to the farmers

Assuming that the following aquifer management plans are the only ones available, which one would you choose?

Aquifer management characteristics	Management plan A	Management plan B	Business as usual
Water quality	Low level	Current level	Low level
Water quantity	Current level	Low level	Low level
Number of jobs in agriculture	1455	1380	1275
Price of water per cubic meter	10% Increase	50% Increase	Same as today

Figure 2. Example of a choice set presented to the public

Assuming that the following aquifer management plans are the only ones available, which one would you choose?

Aquifer management characteristics	Management plan A	Management plan B	Business as usual
Water quality	Low level	Current level	Low level
Number of jobs in agriculture	1455	1380	1275
Environmental conditions	Low level	Current level	Low level
Price of water per cubic meter	50% Increase	25% Increase	Same as today

Survey Administration and Sampling

The CE surveys were implemented in February and March of 2008. The farmer survey was conducted in seven villages that use the aquifer's water for irrigation, while the public survey was conducted in the city of Limassol. A sample of 160 farmers (almost 11 percent of the approximately 1500 farmers in the Akrotiri aquifer area) was considered appropriate for the farmer survey, given the time and budget constraints of the project. In each village, the farming households were identified through census data and input from the village mayors; 12-15 percent of the listed farmers were randomly selected and contacted to arrange face-to-face interviews. Those that agreed to participate in the survey were interviewed the following day. The respondents were typically the household members who were responsible for making farming decisions. Since a face-to-face survey mode was used, the response rate was high; 94 percent of the contacted farm households were subsequently interviewed, yielding in 150 completed questionnaires.

The resident CE was conducted in Limassol. At the time of the survey, there were approximately 32,000 households in the city of Limassol. A quota sample of 350 households (i.e. 1.1 percent of the population) was within the budget and time constraints of the research project. In order to make the survey representative of the Limassol population, data were collected from four neighborhoods stratified according to their distances to the aquifer, income levels, and main residential water sources. Streets in each neighborhood and buildings on each street were randomly selected. Face-to-face interviews were conducted with 300 heads of households, yielding an 85.7 percent response rate.

For both surveys, the interviewers began by stating the aim of the overall project, which was to investigate farmers' and residents' opinions on the proposed use of treated wastewater for replenishment of the Akrotiri aquifer. This was followed by a description of the survey (e.g., its duration and the kind of questions that were to be asked, along with assurances that answers would be treated in the strictest confidence and there were no right or wrong answers). The interviewers then read a statement describing the current water conditions in Cyprus in general and in the Akrotiri aquifer and wetland in particular. The respondents were reminded that there is an ever-increasing scarcity of water quality and quantity in the Aquifer. The interviewers then explained that according to the EU WFD, the government must provide long-term water security/safety for farmers and minimize the ecological impacts of water shortages, and that one way this aim could be achieved would be the implementation of an aquifer management plan through which treated wastewater would be channeled from Limassol and nearby villages into the aquifer, in order to replenish its groundwater supplies. The respondents were then acquainted with the definition of treated wastewater, as well as its potential uses and possible disadvantages.

Following this introduction, the interviewers described the attributes and levels used to define the aquifer management plan for the purposes of the survey. The respondents were then presented with the eight choice sets, and were asked to state their preference in each choice set. Respondents that consistently selected the opt-out alternative were asked follow-up questions in order to identify their motives and allow them to be classified as protestors or true zero values. Protest responses could indicate an unwillingness to place a price on environmental or social (employment) attributes, and thus an unwillingness to engage in trade-offs involving these attributes and the monetary attribute (Spash and Hanley 1995; Spash 2006). Alternatively, opt-out responses could signal that the respondent objected to the experimental design or the utilized valuation scenario.

In the farmer CE, the respondents identified as protestors were those who agreed with one of the following statements: "I shouldn't be asked to pay for the water under my land;" "I do not believe that aquifer recharge with treated wastewater will succeed in improving conditions;" "I don't believe that recycled water is safe," and "I don't believe that recycled water is appropriate for farming." Among the respondents, eight were identified as protestors and excluded from the sample. The final farmer CE sample consisted of 142 respondents.

Similarly, in the resident CE, the respondents identified as protestors were those that agreed with one of the following statements: "I do not want to pay increased water rates;" and "I do not believe such a recycled water use program would work efficiently, effectively and safely in Cyprus." Overall, 14 households were identified as protesters of the aquifer management plan and removed from the resident CE sample, resulting in a final sample of 286 respondents.

Comparison of descriptive statistics for the farmers' and residents' sample averages with their population statistics (Census of Agriculture, 2003 and Cyprus National Statistics, 2007) revealed that the farmer and resident samples are representative of their respective populations in terms of household size, age of the household head, and income.

Results of the Choice Experiments

For analysis, the CE data are coded according to the levels of the attributes. Attributes with two levels (i.e., water quality/quantity, and ecological conditions) enter the utility function as binary variables, with the effects coded as 1 to indicate current level and -1 to indicate low level (Louviere et al. 2000). Attributes with four levels (e.g., employment and price) enter in cardinal-linear form.

We hypothesize that farmers will prefer aquifer management plans that maintain current levels of water quality and quantity in the long run. Therefore, the signs on these attributes are expected to be positive. For the farmer CE, the sign on the number of agricultural jobs could be either positive or negative depending on whether their altruistic motives outweigh their preferences for less competition for the scarce water resources. In the resident CE, we hypothesize that residents would prefer the area's water quality and ecological conditions to be maintained at their current levels (i.e. positive coefficients are expected for these two attributes), due to the indirect use (through local food supply and maintenance of the hydrological balance in the area) and non-use (conservation of biodiversity in the wetland) values, respectively, generated by these attributes. In addition, we expect that residents would prefer a higher number of agricultural jobs to be maintained in the area, due to the non-use values associated with knowing that others are employed and keeping rural areas active. In line with economic theory, we expect the coefficients for the monetary attribute to be negative in both the farmer and public CEs, since respondents would prefer options with lower prices.

The CEs are designed under the assumption that the observable utility functions follow strictly additive forms. The models are specified such that the probability of selecting a particular aquifer management plan is a function of the plan's attributes. Two basic Conditional Logit Models (CLMs) are estimated, one for the 1136 choices elicited from 142 farmers, and the other for the 2288 choices elicited from 286 residents. For the CLM to be considered a suitable model for the analysis of choice data, the Independence of Irrelevant Alternatives (IIA) property should hold. The IIA property is tested with a Hausman and McFadden (1984) test and the results are reported in Table 2.

Table 2. Hausman and McFadden tests for the farmer and resident CEs

Excluded option	Farmer CE	Resident CE
Excluded option	X^2 df=4 (p)	X^2 df=4 (p)
Aquifer management plan 1	75.0110 (0.000000)	143.7184 (0.000000)
Aquifer management plan 1	66.6280 (0.000000)	140.4134 (0.000000)
No aquifer management plan	Could not carry Hausman and McFadden test for IIA. Difference matrix is not positive definite.	

According to this test, the IIA property does not hold, and thus the tested CLMs are not the appropriate models. To improve model fit and estimate more accurate models of choice, CLMs with interactions are estimated for both CEs, using farmer and household-level characteristics that are expected to affect the respondents' choices of aquifer management plan (Rolfe et al. 2000). According to the results from a Swait-Louviere log likelihood ratio test, CLMs with interactions improve over the basic CLMs at the 5 percent significance level. These results are reported in Table 3.

Table 3. Conditional Logit Model (CLM) with interactions for the farmer and resident CEs

	Farmer CE	Resident CE
Attributes	Coefficient (standard error)	
Water quality	0.248*** (0.065)	0.466***(0.151)

Table 3. (Continued)

	Farmer CE	Resident CE
Water quantity	0.310*** (0.080)	-
Agricultural employment	0.004*** (0.0004)	0.003***(0.0003)
Ecological conditions	-	0.436***(0.051)
Price of water per m^3	-26.122*** (4.450)	-6.299***(1.809)
Water quantity * total cultivated irrigated area	$0.417*10^{-5}$** ($0.180*10^{-5}$)	-
Water quantity * % water from well	0.531***(0.204)	-
Employment in agriculture * % water from well	-0.003***(0.001)	-
Price * years of experience	0.344**(0.158)	
Price * full employment	-	2.018** (0.992)
Water quality * % potable water from tap	-	0.689***(0.162)
Price * % potable water from tap	-	-3.284*(1.753)
Log likelihood	-999.103	-2170.895
ρ^2	0.133	0.131
Number of observations	1136	2288

Source: Akrotiri Aquifer Farmer Water Management and Resident Water Valuation Surveys (2008)

Asterisks indicate * 10%, ** 5% and *** 1% significance levels obtained with two-tailed tests.

The first column of Table 3 gives the results of the CLM-with-interactions for the farmer CE. The overall fit of the model, as measured by McFadden's ρ^2, is satisfactory by the conventional standards used to describe probabilistic discrete choice models (Hensher et al. 2005). The results reveal that all attributes included in the definition of the aquifer management plan are highly significant determinants of the respondents' aquifer management plan choice. The positive coefficients on the quality, quantity and agricultural employment attributes indicate that farmers are more likely to choose alternatives that maintain the current conditions of these attributes. As predicted by economic theory, the coefficient for water price is negative, suggesting that farmers are more likely to choose aquifer management plans with lower water prices. The magnitudes of the coefficients for the binary attributes of water quality and quantity indicate that (among these attributes) water quantity is the most important determinant of farmers' choice, followed by water quality.

The results of the interactions yield three interesting findings. First, farmers that cultivate larger irrigated areas and those that acquire greater proportions of their irrigation water from the aquifer through wells on their farms are more likely to select aquifer management plan alternatives that maintain the current water quantity. Undoubtedly, these farmers would like to continue to use the aquifer (or have the option to do so) for irrigation. Second, those farmers who extract greater proportions of their irrigation water from the aquifer through wells are more likely to select aquifer management plan alternatives that propose to provide fewer agricultural jobs. This result signifies the competitive aspects of water use in the area. Farmers that rely on the aquifer for irrigation recognize the negative externality associated with the greater availability of water for other local farmers.

A similar motivation can be inferred from the third finding, namely that of a positive and significant coefficient for the interaction between water price and farmers' years of experience. More experienced farmers are likely to realize that overexploitation of the water in the aquifer creates negative externalities that should be internalized in order to maintain the area's irrigated agriculture. On a final but related point, farmers with greater experience are likely to be exclusively dependent on farming for their livelihoods. They may seek measures that will restrict the entry of other farmers in order to limit competition. The motivation for limiting competition can be attributed to two complementary underlying factors: First, a tacit collusion argument implies that fewer farmers can collude to produce lower quantities and thus maintain high prices. Second, higher water prices (and hence high farming costs) can discourage new entrants into farming in this area.

Overall, the CLM-with-interaction results for the farmer CE reveal that there are significant economic benefits to be gained from the maintenance of water quantity and quality at their current levels through replenishment of the aquifer with wastewater treated to a high quality. At the same time, the low number of protestors (approximately 6 percent of the sample) suggests that the plan to replenish the aquifer with treated wastewater is widely accepted by farmers. Nevertheless, it is worth noting that the surveys were implemented following one of the worst droughts in the area's recent history. This could have biased farmers' attitudes in favor of aquifer replenishment with wastewater, even if under normal circumstances they would have regarded treated wastewater as a last resort for tackling the water scarcity problem.

For the resident CE, the fit of the CLM-with-interactions is satisfactory, and the model results indicate that (similar to the farmer CLM) all of the attributes are highly significant determinants of aquifer management plan choice. Residents are more likely to select alternatives that maintain the current water quality. They also tend to prefer management plans that generate higher agricultural employment and maintain the area's current ecological conditions. The magnitude of the estimates indicates that, among the binary attributes, water quality is the most important determinant of individual choice. As predicted by economic theory, the coefficient for the price attribute is significant and negative, indicating that residents are more likely to choose aquifer management plans that are associated with lower water prices.

The significant interactions in this model reveal that respondents who are employed full-time (i.e., those who have higher and steady household incomes) are more likely to spend more for an aquifer management plan. This finding is similar to those of several other environmental valuation studies in which richer households with predictable income streams were found to be more likely to purchase and pay for environmental goods and services provided by wetlands (see e.g., Birol et al., 2006; 2008). Moreover, residents who rely on tap water for potable (drinking) water are more likely to select aquifer management plan alternatives that maintain the current water quality. Even though these residents do not rely on the aquifer for domestic water, this finding signals that they are aware of an underlying motivation to maintain water quality in the aquifer, i.e., to avoid deteriorating spillovers from the aquifer to other neighboring sources of potable water. Finally, those residents who rely on tap water as drinking water are more averse to higher water prices, as would be expected according to the economic theory.

Table 4 shows the WTP estimates for the two CEs using the sample averages for the farmer and resident characteristics included in the interactions. These WTP values are derived from the estimated coefficients given in Table 3. The estimated WTP values suggest that farmers would be willing to pay (Cyprus Pound)2 CYP 0.014 per m3 of water to maintain current water quality, CYP 0.028 per m3 of water to maintain current water quantity, and CYP 0.0002 per m3 of water to maintain one extra job in agriculture. According to the resident CE, respondents are willing to pay CYP 0.133 per m3 of water to maintain current water quality, CYP 0.055 per m3 of water to retain current environmental conditions, and CYP 0.0004 per m3 of water to sustain one more farmer in the area. Thus, compared to farmers, residents are willing to pay significantly more to maintain current water quality and sustain agricultural employment in the area.

In order to assess the TEV of an aquifer management plan that would maintain current water quality, quantity and ecological conditions, and sustain the highest possible agricultural employment (1500 jobs), we next calculate the compensating surplus (CS) for both CEs. The resulting CS values are CYP 0.087 per m3 of water for farmers and CYP 0.278 per m3 of water for residents.

[2] CYP 1= US$2.44 as of September 2, 2009 (http://www.xe.com/)

Table 4. Average farmer and resident Willingness to Pay (WTP) values for aquifer-management plan attributes in CYP per m^3 of water per household (95% CI)

Attribute	Farmer WTP	Resident WTP
Water quality	0.014*** (0.01-0.018)	0.133*** (0.122-0.144)
Water quantity	0.028***(0.024-0.032)	-
Ecological conditions	-	0.055*** (0.054-0.0551)
Agricultural employment	0.0002***(0.00018-0.00022)	0.0004***(0.00033-0.00047)
CS for the plan with the highest levels of all attributes	0.087 (0.0745-0.0995)	0.278 (0.2503-0.3049)

Asterisks indicate * 10%, ** 5% and *** 1% significance levels obtained with two-tailed tests.

4. COST BENEFIT ANALYSIS AND LONG-RUN DISCOUNTING

Theory of Long-Run Discounting

The realization that projects or policies implemented today may have long-run consequences presents a new challenge when decision makers assess their desirability. This goal here is known as "sustainable development." In a classical CBA, the economic efficiency of projects or policies with long-run-accruing costs and benefits is often assessed using the net present value (NPV) rule. The use of the classical NPV rule is, however, problematic when constant discount rates are used across all time periods, thereby eliminating the influence of the future generations' welfare on the outcome. The deleterious effects of exponential discounting ensure that policies or projects that benefit distant-future generations at the cost of present generations are less likely to be seen as efficient, even if the benefits are substantial in future-value terms. In other words, from the perspective of social choice, the present holds a dictatorship over the future, undermining intergenerational equity. This is an important component of the sustainable-development concept.

The practice of discounting the future has long been controversial, especially within the CBA context (Portney and Weyant 1999). Many economists have argued that for social decisions, anything other than a zero rate of pure-time preference (ρ in equation 1 below) is unethical (for review see Hepburn et al. 2009).This, however, contradicts human behavior, which may be better described by the less demanding standards of "agent-relative ethics" (Arrow 1999). Nevertheless, this ethical perspective for neutrality between generations has a long and fine intellectual history (see e.g., Ramsey 1928; Pigou 1932; Koopmans 1965; Rawls 1971; Solow 1974) and seems particularly compelling for long-run challenges. Moreover, as argued by Dasgupta and Heal (1979), "one might find it ethically feasible to discount future utilities at positive rates, not because one is myopic, but because there is a positive chance that future generations will not exist." The present paper, however, is not concerned with the choice of an ethical stance towards the interests of future generations, except to say that sustainable development, as a widely stated goal of international policy-making (e.g., the EU WFD), will require that we pay attention to the intergenerational effects of current decisions. This is particularly true in the context of water management-related projects, such as the one studied herein.

The last few years have brought important advances in our understanding of time preference and social discounting (for review see Groom et al. 2005; Pearce et al. 2003; Koundouri 2009). In particular, several rationales for the use of efficient time-varying — particularly declining — social discount rates have emerged. These rationales range from the ad hoc to the formal; some are founded solely in economic theory, while others consider principles of intergenerational equity. Our view of the relevant, admittedly complicated, literature is that there are three powerful reasons that could explain why the social time preference rate might decline as the time horizon extends. First, uncertainty about the future, whether in terms of future economic growth or the future social time preference rates themselves, results in a declining rate (see for example, Gollier 2002a; 2002b; Weitzman 1998; 2001; 2007). Second, considerations of intergenerational equity and future fairness argue against a discount rate that gives the present generation a dictatorship over future generations (see for example, Chichilnisky 1996; 1997; Chichilnisky and Heal 1997; Heal 1998; 2003; Li and Lofgren 2000). A related strand of recent literature on CBA of climate change suggests the value of "dual-rate discounting," where goods consumption is discounted with a consumption discount rate and environmental consumption is discounted with an environmental discount rate. The motivation for dual-rate discounting is to justify substantial emission reductions, as it is possible in this framework that the environmental discount rate might be lower than the consumption discount rate, or that (in a model with endogenous dual-rate discounting) both discount rates might decline over time (see for example, Kogel 2009). Third, experimental work by both psychologists and economists on individual choice has revealed that individuals discount the future at a declining rate that follows a hyperbolic path (see e.g., Henderson and Bateman 1995; Karp 2005).

In a deterministic world, the social time preference rate, δ, is commonly characterized by the Ramsey equation (Ramsey 1928):

$$\delta = \rho + \mu g. \qquad (1)$$

This reflects two characteristics of individual preferences that provide a rationale for discounting the future, namely the pure rate of time preference, ρ, and the aversion to consumption fluctuations, which is reflected by μ. The former is commonly known as the utility discount rate and reflects the preference of individuals for present utility over future utility. When utility is the numeraire, ρ is the appropriate social discount rate3. However, the Ramsey rule also provides a complete description of the term structure for the interest/discount rates. More specifically, when the growth rate of the economy is certain and constant, the discount rate should be independent of the time horizon. In risk-free economies with time-varying growth rates, the Ramsey rule becomes:

$$\delta_t = \rho + \mu g_t, \qquad (2)$$

where δ_t is the discount rate associated with time t, and g_t is the annualized growth rate of the economy over period [0,t]. This implies that the discount rates should decrease with maturity in an economy with decreasing expectations, i.e., when the growth rate is expected to diminish in the future.

Granted, it is very difficult to predict the distant future. As a result, all recent attempts to justify a decreasing time structure of discount rates have relied on the introduction of uncertainty. Once the context shifts to one of uncertainty, the case for decreasing discount rates (DDRs) becomes compelling. Theory suggests that, in an uncertain economic environment, the persistence of shocks to the growth rate of consumption (in the consumption-based approach; Gollier 2002a; 2002b) and short-term interest rates (in the production-based approach; Weitzman 2007) determines the shape of the term structure for the socially efficient discount rate. These two explanations are mutually consistent: Persistent shocks to growth expectations translate into persistent shocks to interest rates, both of which yield DDRs. In comparison with the use of a constant discount rate, the use of a DDR increases the weight attached to the welfare of future generations.

The existence of persistence is an empirical question, and the degree of persistence in a series determines the rate of decline of the certainty equivalent discount rate (CER). Newell and Pizer (2003), Groom et al. (2007), and Hepburn et al. (2009) showed how empirical work can measure the relevant parameters of a sequence of an aggregate DDR, as required for the present case study. A convenient proxy for the uncertainty in social discount rates is arguably the uncertainty in the risk-free interest rate on government bonds. In an important paper on discounting under uncertainty, Newell and Pizer (2003) made effective use of this proxy. Employing a simple autoregressive model of interest rates in the United States, they derived a working definition and estimation of the CER for use in CBA. Their analysis confirmed that the CER largely declines through time, and the rate of decline is a function of the uncertainty and the persistence in past interest rates. Recently, Groom et al. (2007), Hepburn et al. (2009), and Gollier et al. (2008) argued that such a simple autoregressive model is unlikely to be sufficiently versatile to reproduce the empirical regularities typically found over the long run in interest rate series. These authors emphasized the importance of econometric model selection for estimating the schedule for the empirical discount rates appropriate for CBA in many countries.

Following this literature, the key assumption of our adopted framework is that of a declining but time-stable structure of discount rates. This assumption allows us to connect the representative-individual intergenerational theory and the empirical treatment of country-specific historical data. To do this, we utilize the DDR trajectory estimated by Gollier et al. (2008), who used a univariate model describing the uncertainty in the behavior of interest rates and very long-run historical data on centuries of historical

[3] The discussion surrounding the Stern Review of climate change was very useful in pinpointing the various meanings of the components of the Ramsey equation (see, e.g., Weitzman 2007b; Quiggin 2008; Cole 2008). We want to thank an anonymous referee for raising this point.

events that affected the stochastic characteristics of the interest rate series to describe the stochastic dynamics of the real interest rate and estimate a theory-consistent schedule of DDR.

The main point we want to share through the use of this trajectory is that the long-run trajectory of the decline in discount rates can be estimated without using a structural model. It is true that the relevant literature contains numerous studies that define structural models wherein the yield curve is determined by a number of factors, such as the growth rate of consumption or the short-term interest rate. However, all of these structural models are based on specific assumptions, and their behaviors are sensitive to these assumptions. Empirically, structural models often create "economic puzzles" because they fail to explain what is actually observed in the markets. Structural uncertainty about extremely bad events (such as world wars and geophysical catastrophes) dramatically changes the dynamics of a structural model. Moreover, the rareness of extremely bad events makes it difficult to accurately estimate their possibility of occurrence based on available historical data. In general, structural parameters are empirically difficult to estimate, meaning that the behavior of structural models will critically depend upon the prior beliefs of the researcher.

An alternative way to describe the dynamics of interest rates is through a simple univariate time series model, where the future properties of the interest rate are determined by its own past behavior. The uncertainty surrounding the future path of the interest rate (captured by the uncertainty in the estimated parameters of the univariate time series model) suggests the use of DDRs. We argue that the empirical simplicity and theory-consistency of this approach makes it preferable to the alternative approach of utilizing a structural model to characterize the dynamics of interest rates. Here, we perform the CBA that uses a DDR trajectory estimated through a univariate time series model.

Application of the Long-Run CBA to the Case Study

The CS values calculated in Section 3 reveal that the maintenance of the current water quality, water quantity, employment status and ecological conditions in the Akrotiri wetland area are likely to generate significant use and non-use values to the major stakeholders. The majority of the direct-use and option values are expected to be appropriated by the local farmers, who will be the sole users of the aquifer water once the recharge takes place. Hence, the total use value of the recharge is given by the product of the CS for the average farmer under the aquifer management plan (CYP 0.087 per m^3 of water) and the total treated wastewater that will be used to replenish the aquifer, which is expected to be 6 million m^3 per year. The annual direct use and option values are therefore estimated to be CYP 522,000.

Non-use and indirect use values are enjoyed by area residents, as represented by sampled households in the city of Limassol. For residents, the non-use and indirect use benefits are calculated as the product of the CS for the average member of the public under the aquifer management plan, and the total consumption of water in Limassol, which is estimated at 12.74 million m3 per year. The annual indirect plus non-use value is calculated to be CYP 3.54 million per year, and the TEV of the aquifer management plan amounts to CYP 4.07 million per year.

The cost of the aquifer-recharging plan includes the fixed costs of developing the infrastructure needed to recharge the aquifer with the treated wastewater, as well as the variable costs of the wastewater's treatment. The fixed costs of infrastructure development (including the pipes and the construction of boreholes) are estimated to be CYP 100,000, while the capital and operation costs (including transportation of the wastewater) are estimated at CYP 0.07 and CYP 0.05 per m3 of treated wastewater, respectively. For 6 million m3 of treated wastewater, therefore, the variable costs amount to an overall cost of CYP 720,000 per annum (Aeoliki foundation, personal communication).

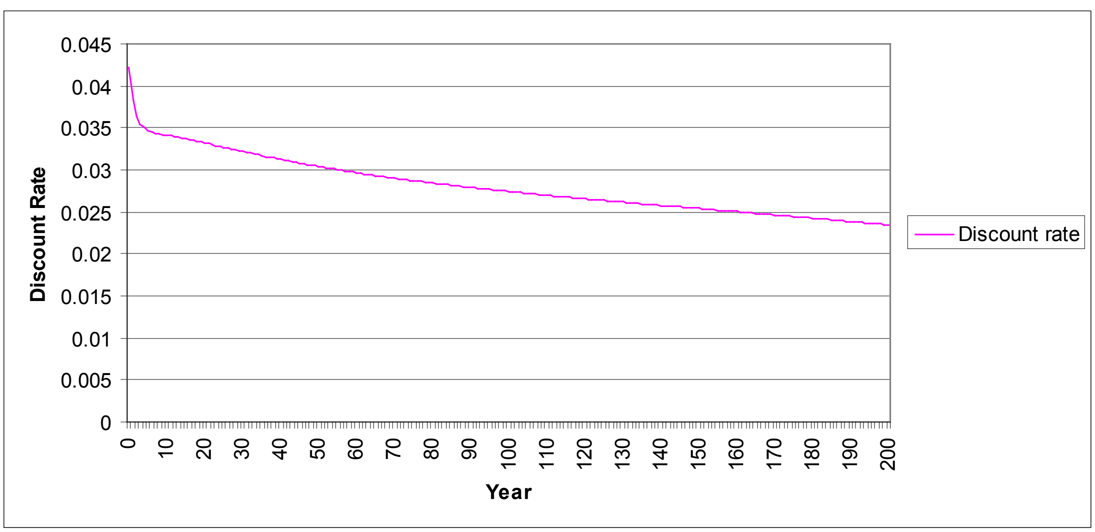
We next use these cost and benefit figures for a thorough long-run CBA, in order to determine whether the implementation of the aquifer management plan will yield a Pareto (welfare) improvement. According to our consultations with hydrologists, ecologists and local water policy makers, if the aquifer management plan is implemented and sustained, the current ecological, water quality, water quantity, and employment conditions in the area can be maintained in the long run, extending to approximately 200 years. Our approach to examining the future net benefits of the plan is conservative; we assume that the cost of the recharge will not decrease due to technological changes, and that water consumption will remain constant. We also assume that the benefits to farmers and residents will remain constant over time. The classic NPV rule is applied, and two constant discount rates (3.5 and 6 percent) are used to calculate the NPV using the average-, upper- and lower-bound CS values for the farmers and residents. Constant discount rates of 3.5 and 6 percent are selected because 3.5 percent reflects the suggested current best-practice for short term investment projects (under 30 years) in a small number of OECD countries (e.g. United Kingdom, HM Treasury, 2003), whereas 6 percent is commonly used in most of the OECD countries. The results are shown in the second and third columns of Table 5.

Table 5. Net present value (in CYP) for 200-year horizon and varying discount rates (in millions)

	Constant 3.5%	Constant 6%	Declining
Average CS	95.37	55.65	107.4
Lower-bound CS	83.13	48.51	93.62
Upper-bound CS	107.27	62.6	120.81

Due to the absence of long-run data on discount rates in Cyprus, we use the optimal "world" trajectory of the DDR estimated by Gollier et al. (2008) to assess the long-run economic viability of the aquifer management plan under consideration. Gollier et al. estimated country-specific DDR trajectories and then constructed a weighted world-average DDR based on the GDP of each country measured in Purchasing Power Parity (PPP) terms. In their analysis, the weight for each country equaled the ratio of its GDP over the sum of the GDPs of all countries under consideration. The DDR estimated by Gollier et al. started at 4.5 percent, declined sharply during the first decade, and then declined gradually for the next 190 years until it reached approximately 2 percent at year 200. Figure 3 illustrates this DDR trajectory, which is used in the present study.

Figure 3: Trajectory of the utilized Declining Discount Rate (DDR) over 200 years

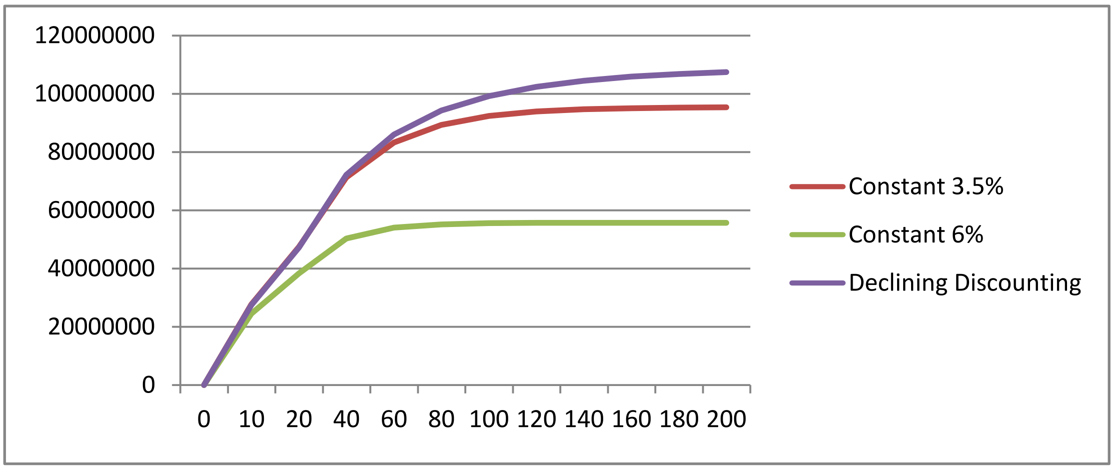


Source: Authors.

The NPVs for the average-, upper- and lower-bound CS values are estimated with the DRR, and the results are shown in the final column of Table 5. Under the DDR, the average NPV is CYP 107.4 million. This is approximately 1.13, and 1.9 times the NPVs found under the constant exponential discount rates of 3.5 percent and 6 percent, respectively. The NPVs for the lower- and upper-bound CS estimates follow the same pattern.

Overall, the CBA results reveal that the aquifer management plan generates substantial economic benefits (i.e., both use and non-use values), resulting in a positive NPV irrespective of the implemented discounting scheme. The NPVs obtained under the DDR are, however, significantly higher. This illustrates the importance of using DDRs for projects and policies that are expected to have impacts far into the future, and also emphasizes the significance of weighing the economic benefits to future generations. As illustrated in Figure 4 below, the NPV under constant exponential discounting becomes noticeably flatter after the first 60 years for the 6 percent and after 110 years for the 3.5 percent constant discount, while the NPV under the DDR plateaus after 180 years.

Figure 4: Net Present Value (NPV) for average compensating surplus (CS) values over the next 200 years



Source: Authors

These findings are especially important in the context of the implementation of the EU WFD, since the Directive promotes the notion of "sustainability," the need to capture all costs and benefits, and the necessity of performing a thorough CBA of various measures and technologies to ensure that the adopted instruments are the most economically efficient choices for a given country's different water resources.

5. POLICY IMPLICATIONS AND CONCLUSIONS

This paper demonstrates a comprehensive framework for assessing the viability of an environmental management plan that has long-run economic and ecological impacts. The environmental management plan considered herein is an aquifer management plan that proposes to replenish a depleting aquifer with treated wastewater. The studied case is that of the Akrotiri aquifer in Cyprus, a water-scarce region of the world.

The framework is implemented in three stages: First, the main stakeholders that would bear the costs of and derive the benefits from this plan are identified through various qualitative methods (e.g., focus group discussions, informal interviews with the public, and consultations with experts and policy makers), as well as through thorough literature reviews on aquifer management in water-scarce regions in general and on the Akrotiri aquifer and wetland in particular. The key stakeholder groups identified as benefiting from the aquifer are local farmers and residents in the nearby city of Limassol. The former derive direct use and option values from the aquifer, as they depend on the quality and quantity of water for their livelihoods, whereas the latter derive indirect use values through the consumption of locally produced vegetables, as well as non-use values from the ecological status of the local environment and from the agricultural jobs supported by the aquifer.

Second, two distinct CEs are implemented with these two stakeholder groups, in order to capture the specific economic values that each stakeholder group derives from such a plan. In the farmer CE, the aquifer management plan is defined in terms of the quality and quantity of water in the aquifer and the number of farmers that can be employed in the area's agricultural sector. For the resident CE, the aquifer management plan is defined in terms of water quality, agricultural employment and the area's ecological conditions. In both experiments, the utilized payment vehicle is an increase in the price per m3 of water consumed by the farm/household. The CE results reveal that, on average, the farmers and residents are not opposed to an aquifer management plan that proposes to replenish the aquifer with treated wastewater. Both stakeholder groups realize significant compensating surplus values, and such a plan would generate both use and non-use values.

Third, the long-run economic efficiency of implementing such a plan is assessed. To this end, a CBA is conducted and the estimated economic values (benefits) accrued by the two stakeholder groups (measured in CS terms) are aggregated over their relevant populations and added to capture the total economic value (i.e. total economic benefits) generated by the plan. The calculated total economic benefits are weighed against the total (fixed and variable) costs of implementing such a plan. Since this proposed plan is expected to have long-run impacts on the local economy and ecology, the plan's sustainability is tested using a long-run cost CBA, and the net present value (NPV) of the plan is estimated using two different discount rate schemes, namely constant (3.5 and 6 percent) and declining discount rates (DDRs).

The NPV results reveal that the net benefit generated by the plan is positive and significant well into the future, regardless of the utilized discount rate scheme. The implementation of this plan would yield a welfare (or Pareto) improvement that would not only increase economic benefits to all the stakeholders in both the short- and long runs, it would also help Cyprus in its efforts to meet the EU WFD requirements by 2015.

The NPV results, however, reveal that the net benefit trajectory estimated with the DDR is higher than those estimated with the constant discount rates. Moreover, depending on the constant discount rate used, the net benefits under the DDR trajectory take one and a half to three times as long to come to a plateau. These findings indicate that DDRs should be used whenevaluating projects or policies with long-term impacts, in order to ensure the attainment of sustainable development goals.

Overall, this methodology is recommended for the assessment of any environmental plan that is expected to have long-run economic and ecological impacts that would affect various stakeholders (including future generations). In particular, this framework would be useful for EU member states that are obligated to implement the WFD, which explicitly calls for estimation of the total economic value of a potential plan, consideration of the costs and benefits that would accrue to different stakeholders, and the application of a thorough CBA that takes sustainability into account.

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