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Ranking supply oriented policies of water management policies from institutional stakeholders' political views

A Delphi survey on irrigation water in the Júcar basin area

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Abstract: This paper is a case study concerning water policies to be established for the Júcar basin in Mediterranean Spain. The objective of the research is to provide reliable information on the institutional stakeholders' judgements and values about these potential policies in the basin. This is relevant to water authorities whose decisions should be made by testing if the policies proposed by planners are acceptable to institutional stakeholders in the area. We consider only supply oriented policies, as demand oriented policies (although interesting) require paying strong subsidies to be acceptable to farmers. Information is collected by a Delphi survey, which was taken by a representative sample of institutional stakeholders. They evaluated twenty potential policies of irrigation water from eight economic, environmental, social and political criteria. The assessments were aggregated by multicriteria analysis, leading to a political ranking of policies. As the main results, the top ranked and the second ranked policies are "desalination combined with higher water prices and even with interbasin water transfer" and "groundwater control combined with interbasin water transfer", respectively.

Key words: Mediterranean basins, irrigation water, institutional stakeholders, water policy ranking, COBB method, Delphi surveys

1. INTRODUCTION

Water use planning for irrigation land is often undertaken by analytical models (e.g., Albiac et al., 2008; Bravo and Gonzalez, 2009). However, the analytical results should be confronted with stakeholders' views in order to make decisions. In our context, stakeholders are institutions, associations and unions involved in the water problem in the area. Particularly, the views expressed by representatives, experts, delegates and spokespeople of water agencies, farmers associations, ecologists associations and trade unions should be deemed relevant to help governments make final assessments and decisions.

This paper aims at the following objectives.

1. To investigate how institutional stakeholders evaluate public policies of irrigation water supply, control and efficiency from different economic, environmental, social, etc. criteria. As these assessments involve political views, they will be coloured by subjective judgments, values and group interests. For this purpose, we consider 20 supply oriented policies of water management for irrigated land to be potentially applied in the Júcar basin area (our real world scenario). In our context, "supply oriented policies" is a wide notion including increasing supply, water restrictions, groundwater control, allocation, regulated prices, and others. A Delphi survey is conducted through a Delphi panel, whose members were commissioned by institutional stakeholders in the area.
2. To rank the above policies by a composite index of criteria aggregation. For this purpose, a new ranking model is used requiring the following tasks: (a) establishing a weak ordering of criteria given uncertainty, namely, the relative importance between two criteria may or may not be uncertain to the analyst; and (b) aggregating the criteria by a Cobb-Douglas function whose parameters are estimated from the criteria ordering using a recently proposed

technique (Ballestero, 2006). Hereafter, this technique will be called the COBB method (Criteria Ordering from Bounded Beliefs).

There are critical reasons to exclude demand oriented policies from the survey. Although these policies can be viewed as interesting alternatives, they are very difficult to apply in Spain today, given the economic circumstances. In fact, implementing demand oriented policies in an efficient way requires paying strong incentives/subsidies to thousands of farmers. Policies such as alternative crop schemes and improved irrigation schemes by using modern technology require high levels of subsidies –if not, these policies will not likely be accepted by most of the farmers. If subsidies are not paid, then a policy such as using appropriate technology to save water in irrigated farming becomes a mere recommendation but not a proper demand oriented policy. Today, and for the next decade or longer, the Spanish governments must make a wise policy of budget and public expenditure, moving within a regulatory framework where more subsidies to farmers are ruled out. Conversely, supply oriented policies involve minor concern about subsidies (see section 3.2 later). Notice that the purpose of this paper is not to evaluate potential policies in a strict scientific framework. How and where the potential measures should be applied is not our objective either. Conversely, the purpose is to investigate judgments and reactions of institutional stakeholders, by asking them about their evaluations of policies based on different criteria. Representatives and experts of these institutional stakeholders are not scientists or they do not act as scientists themselves. Therefore, their political views (economic and social judgments) can be a departure from scientific assessments relying on analytical models. Indeed, to know what the institutional stakeholders think of government potential policies is of great importance to governments, although their opinions are not necessarily scientific/strictly scientific. Thus, the Delphi results are useful to test political/social assessments and acceptance of the twenty policies in the area.

There is specific literature on ranking water management policies. Reviewing this literature is not an objective of this paper, but some illustrative references can be provided. AlKloub et al. (1997) deal with water projects in Jordan to be ranked by a multicriteria technique based on the hierarchy of the water sector objectives and their weights. This is achieved from an organized brainstorming workshop in which the participants were key decision makers. In another paper (Arhonditsis et al., 2002), the objective is to rank coastal scenarios from economic and environmental inputs by assigning user's weights/priorities. De Kort and Booij (2007) use Monte Carlo analysis to rank water management policies/measures whose impacts should be evaluated under uncertainty. This is applied to flood control measures such as dike heightening and others. Dealing with an irrigated area in northern Spain, other researchers (Raju and Duckstein, 2004) establish a ranking of water planning strategies from a broad range of criteria whose size is reduced by cluster analysis. Once this simplification is made, ELECTRE III (Roy, 1978) is applied to rank under uncertainty. If these works are compared to our research, notice that the five works widely differ from one another concerning methodology. Both the first cited paper and our paper rely on opinions from relevant stakeholders; however, we use a Delphi survey, which appears to be a more precise technique than brainstorming. Like the last two papers, our approach involves uncertainty; however, methods and scenarios are a departure from our approach. Indeed, northern Spain is a cold inland region, its climate, crops and irrigation problems being very different from those of the mild Mediterranean climate. Fuzzy judgment ranking methods and integrated assessment techniques are also applied to water resources decision making. Although they could be considered to be somewhat related to our proposal, they fall outside the scope of this paper.

There are many multicriteria applications to water-related decisions; here, we will only cite a few concerning irrigation environments in Mediterranean Spain (Gómez-Limón and Martínez, 2006; Riesgo and Gómez-Limón, 2006; Gonzalez and Bravo, 2006).

This paper is organized as follows. In Chapter 2, the geographic setting is described. In Chapter 3, the Delphi survey, the standard irrigation policies and the assessment criteria are defined. Analytical developments are presented in Chapter 4, including the policy rankings, while the results are discussed in Chapter 5, including a sensitivity analysis. The paper closes with concluding remarks.

2. THE JÚCAR BASIN AREA IN EASTERN SPAIN

This area includes several Mediterranean basins stretching from Gola del Segura to the Cenia river of 42988.6 km^2 spreading over 6 Spanish provinces, the main one being Valencia. This area recently counted a total population of around 4200000, apart from tourists and immigrants. Land is characterized as follows: (a) Hilly inland with hills higher than 1500 metres; (b) Mediterranean coast embracing plains, valleys and mountains. Most soils (around 85%) contain lime and are calcareous. There are inland clayey valleys, e.g., Navarrés, Ayora and Villena valleys, together with fertile land in the coastal plains. Coastal lakes and lagoons, called “albuferas”, sometimes appear. Climate is typically Mediterranean, warm to hot, with long dry summers and cool wet winters. Temperatures vary greatly from inland to coastal areas due to sea winds. Autumns are rainy (around 50% of annual rain), summers are dry, and the other seasons are moderately rainy. According to an official estimation, irrigated farming in the Júcar area would reach 384802 ha in the 2008 horizon (Plan Nacional de Regadíos-Horizonte 2008). Most significant irrigated land spreads over a coastal strip. In this area, farming is intensive, devoted to orange and other citrus groves, orchards and rice, the latter on the decline. Dry farming of minor importance includes vineyards, cereals and olive groves.

Table 1. Júcar hydrographic area: Expected water shortages for year 2015

Basin	Sustainable water flow, average (SWF)	Expected water consumption (hm^3/year) for 2015 (EWC2015)				Expected shortage
		Urban	Irrigation and livestock	Industry and recreation	Total	
Mijares –Plan de Castellon	100.928	67.74	193	36.19	296.93	-196.002
Palancia-Los Valles	22.211	16.99	72.6	11.31	100.9	-78.689
Turia	94.221	161.1	430.2	72.14	663.44	-569.219
Júcar	317.49	142.97	1304.4	92.6	1539.97	-1222.48
Serpis	36.138	34.24	79.3	11.02	124.56	-88.422
Marina Alta	42.237	39.26	53.2	7.67	100.13	-57.893
Marina Baja	14.136	35.37	33	11.34	79.71	-65.574
Cenia- Maestrazgo	59.261	25.25	81	7.81	114.06	-54.799
Vinalopó-Alicantí	18.392	109.84	105.4	39.96	255.2	-236.808
Total	705.014	632.76	2352.1	290.04	3274.9	-2569.886

Table 1 is constructed by the authors from various sources, but primarily from a report published by The Júcar water agency (CHJ) (http://www.chj.es/Organismo/Paginas/Organismo.aspx), as follows.

- SWF = 0.19*OWR (mean value), where overall water resource (OWR) is computed from time series over 1980-2006 (see Table 10 in the cited CHJ report). Reduction factor 0.19 is used for Spanish Mediterranean basins by Tobarra (1996).
- EWC2015 (urban) = [150*365 litre/equivalent inhabitant/year]*[expected number of inhabitants including equivalent tourists].
- EWC2015 (irrigation) = [0.004 hm^3/ha/year]*[expected irrigated land in hectare].
- EWC2015 (livestock) (same amount as in 2005) and EWC2015 (industrial and recreational uses). These are estimated in Tables 24 and 34 in the cited CHJ report.

- Expected shortage. This is the difference between SWF and EWC2015 (total). In all basins, water shortages are expected.

Map 1. Júcar hydrographic area: Rivers and reservoirs

3. DELPHI SURVEY, STANDARD POLICIES AND CRITERIA

First, we describe and motivate the Delphi survey as a critical issue of the paper. After doing this, the twenty policies and the eight criteria will be defined.

3.1 Delphi survey

According to objective 1.1, critical judgments from institutional stakeholders in the area were elicited through a Delphi survey. In November 2005, both the questionnaire and the list of potential panellists were completed. From December 2005 to March 2006, the questionnaire was sent to 32 appointed panellists, with precise instructions on the Delphi process. In 2006, 12 stakeholders accepted to take the survey, while the remaining 20 potential panellists did not. Most of the latter justified their refusal. Indeed, this 62.5% of the invited panellists who refused to participate is not rare in Delphi surveys. This is because: (a) to complete Delphi questionnaires requires long time and work of experts and managers; (b) if the panellist is an institutional stakeholder, then the questionnaire should be approved by the board of directors, but an agreement in the board is often difficult to reach. Concerning the survey, one can wonder if the data from year 2006 are still valid. From recent enquiries carried out by the authors, no institutional stakeholder who accepted the Delphi survey has stated opinions/made declarations contradicting their previous views of year 2006. Characteristics of this Delphi survey can be summarized as follows.

1. *Panel*. Unlike traditional surveys, Delphi relies on judgments made by a small number of distinguished participants, namely, the so-called Delphi panel of experts/stakeholders. Therefore, we do not choose potential panellists randomly, but we select them by considering their significance as institutional stakeholders. In Delphi surveys, the panellists are typically few; however, Delphi results are probably more informative and reliable than those obtained from traditional surveys based on large samples of unmotivated, anonymous individuals. In our study, the significance of the panel is strengthened by the fact that the panellists are not individuals but institutions. Notice that most potential panellists in our study are associations acting on behalf of their numerous members.
   In Table 2, the potential panellists are classified in seven groups to reflect their particular character. Let us define each group and specify its relative size in the 32-panellist sample of potential panellists, as well as in the 12- panellist sample of stakeholders who completed the survey.

Table 2. Delphi survey: classifying 32 institutional stakeholders in the Júcar basin area (potential panellists). 2005-2006

Character	Number of potential panellists		
	Completed the survey*	Did not complete the survey	Total
Government offices (water agencies and others)	2	2	4
Environmental associations	0	5	5
Farmers Unions/ Trade Unions	2	3	5
Water user associations	5	4	9
Other rural associations	0	4	4
Private centres of rural studies	1	0	1
Rural services companies	2	2	4

** See acknowledgement at the end of the paper.*

- Government offices (water agencies and others). This group includes: (a) public water agencies (called CH in Spanish), which are responsible for water use planning in their respective area, water supply and control; (b) agricultural and environmental protection departments. Both the Júcar CH and the Segura CH (the latter being responsible for a basin area next to the Júcar) were invited to take the survey. However, the Segura CH declined the invitation to participate by arguing inability to deal with Júcar problems. Relative size of the group: 12.5% in the 32- panellist sample, and 16.7% in the 12-panellist sample.
- Environmental associations. These are groups of people with a common interest in protecting the environment, but not especially the rural environment. Relative size: 15.6% in the 32- panellist sample, and 0% in the 12- panellist sample.
- Farmers Unions/Trade Unions. These are active unions extended all over Spain to associate farmers (especially, small farmers). Some of them are rural branches of big trade unions in Spain. Relative size: 15.6% in the 32- panellist sample, and 16.7% in the 12-panellist sample.
- Water user associations. These are local groups of farmers who are associated to manage irrigation in a cooperative way. Relative size: 28.1% in the 32- panellist sample, and 41.7% in the 12- panellist sample.
- Other rural associations. These include rural people in some districts of the area. Irrigation is not their main concern. They are not branches of big trade unions. Due to these

characteristics, their influence over the water supply problem is limited. Relative size: 12.5% in the 32- panellist sample, and 0% in the 12- panellist sample.
- Private centres of rural studies. There are few centres of study dealing with water use policy in the area. Even though they might have some influence as information sources, this influence is limited. Relative size: 3.1% in the 32- panellist sample, and 8.3% in the 12- panellist sample.
- Rural services companies. These are firms offering services of irrigation water management, water conveyance, control, and protection to farmers in some basins, valleys and districts of the area. Some of them are joint ventures with a municipal shareholder. Relative size: 12.5% in the 32- panellist sample, and 16.7% in the 12- panellist sample.

One can wonder if the above relative sizes are appropriate. Consider first the 32- panellist sample of potential panellists. If the private centre of rural studies is overlooked (due to its minor importance), then the relative sizes range between 12.5% and 15.6%, except the water user associations, whose great importance justifies its relative size of 28.1%. In the conclusions of the paper, this bias will be acknowledged. Consider now the 12- panellist sample who took the survey. If the private centre of rural studies (8.3%) and the other rural associations (0%) are overlooked because of their minor importance, then the relative sizes are distributed as follows: (a) 41.7% for water user associations; (b) 0% for environmental associations; and (c) 16.7% for each of the three remaining groups. As the water user associations are of major importance in our context, their high relative size is justified. In the conclusions of the paper, this bias will be acknowledged. Conversely, the zero percentage of the environmental associations might be striking and should be commented. According to their responses, they declined to participate either because of the lack of experts or because of the lack of agreement within the respective boards. Indeed, judging from their public declarations, most ecologists in the area are concerned about problems such as achieving low carbon urban environments, nuclear power plants, forest protection and urban air pollution rather than water supply and demand. Some environmental associations might have had difficulties in evaluating policies that are appealing to ecologists but unpopular to farmers. In any case, the analyst can do nothing to obtain assessments from these critical stakeholders. We acknowledge that losing them biases the results –this is a limitation of the paper (see Chapter 6, Conclusion). However, the environmental postulates are considered in our survey by other institutional stakeholders such as the government offices and the Farmers Unions/Trade Unions, which have environmental departments. Both groups together represent more than 33% in the 12- panellist sample who completed the survey.

2. Survey process. As well known, Delphi is a structured group interaction process that includes two or more rounds of judgment collection and feedback. By March 2006, the questionnaire for the first round was already sent out to the stakeholders. No deadline was set for returning the survey. There were delays due to circumstances such as: (a) each institutional stakeholder had to appoint experts among its members to analyze the questionnaire; and (b) answers from the institution's experts had to be approved by the boards of directors. At the end of June, all surveys had been already returned. Every panellist evaluated each policy from each criterion on a scale from 1 to 5. This scale was interpreted as "the more the better". Therefore, if the institution's judgment was strongly against policy P in the light of criterion C, then P would be evaluated at level 1 from this criterion. On the contrary, if the judgment was strongly in favour of P from criterion C, then this policy would be evaluated at level 5. For example, if policy P is evaluated at level 5 from environmental impact, this means that P does not negatively impact the environment. Once the answers were received, the results were aggregated to obtain mean values, standard deviations and Sharpe ratios (this ratio will be defined in Chapter 5). In the second round (conducted from July 12th to July 24th 2006), the aggregate results of the first round were shown to the institutional stakeholders as feedback.

Each institution had two options: (i) to modify something of its previous judgment under the influence of their colleagues' views; (ii) or alternatively, to maintain its previous assessment. All the institutions chose option (ii).

3. Aggregate responses. In Table 3, the aggregate responses (mean values) are displayed, so that each policy is evaluated from each criterion as an average standpoint of stakeholders. Thus, objective 1.1 in Chapter 1 is achieved. Due to space limitations, other statistical parameters are not recorded in the table; however, they will be useful for discussion in Chapter 5.

Table 3. Delphi survey aggregate responses: Mean values of panellists' evaluations (scale from 1 to 5)

POLICIES	Technical viability	Economic viability	Environmental Impact	Social acceptance	Interregional conflicts	Compliance with European regulations	Compliance with Spanish regulations	Compliance with regional regulations
Inter-basin water transfer (IWT)	2.917	1.889	1.778	2.500	1.222	2.111	2.667	2.667
Desalination (DES)	3.000	3.111	2.778	3.000	3.333	3.333	3.889	2.778
Irrigation water markets (IWM)	2.500	2.778	2.889	2.900	2.222	3.000	3.111	2.333
Irrigation water markets/water banks (IWM/WB)	3.182	2.889	2.889	2.889	2.444	3.111	3.000	2.444
Groundwater control (GC)	3.500	3.556	3.333	2.556	2.222	3.333	3.111	2.222
Allocating less surface water to farmers (LSWF)	3.000	2.889	3.000	1.778	1.889	2.889	2.667	2.000
Higher water prices (HWP)	2.417	2.333	2.889	1.800	2.222	3.000	2.778	1.889
Higher water prices paid by prior rights farmers (HWP-PRF)	2.667	2.444	2.889	1.800	2.375	3.000	2.667	2.000
Irrigation restrictions on some crops (IRC)	3.083	2.556	2.625	2.000	2.000	2.556	2.333	1.556
Irrigation restrictions on some critical areas (IRA)	3.000	2.250	2.889	2.125	2.000	2.667	2.444	1.556
IWT combined with HWP	3.167	2.889	2.222	3.100	1.889	2.444	3.000	3.000
DES combined with HWP and even with IWT	3.333	3.222	3.111	3.300	3.556	3.778	4.111	3.222
IWM combined with HWP-PRF	2.917	2.889	3.111	3.200	2.667	3.444	3.000	2.556
IWM/WB combined with HWP-PRF	3.273	3.000	3.222	3.111	2.778	3.333	3.222	2.778
GC combined with IWT	3.500	3.778	3.778	3.000	2.667	3.333	3.444	2.556
LSWF combined with IWM	3.100	3.111	3.222	2.111	2.222	3.000	3.000	2.444
HWP combined with IWM/WB	2.583	2.375	3.222	2.333	2.556	3.111	3.111	2.222
HWP-PRF combined with IWM/WB	2.833	2.556	3.111	2.333	2.444	3.000	2.778	2.222
IRC combined with LSWF	3.250	2.889	2.889	2.222	2.333	2.667	2.556	1.889
IRA combined with LSWF	3.167	2.778	3.000	2.625	2.222	2.889	2.556	1.889
$\log v_{j\max}$	1.253	1.329	1.329	1.194	1.269	1.329	1.414	1.170
$\log v_{j\min}$	0.883	0.636	0.575	0.575	0.200	0.747	0.847	0.442
$\log v_{j\max} - \log v_{j\min}$	0.370	0.693	0.754	0.618	1.068	0.582	0.567	0.728
Parameters α_j and h_j when criteria ordering $C_1 \approx C_2 \approx C_3 \succ C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$ is considered [equation (1)]								
α_j	5.402	2.885	2.654	1.617	0.936	1.718	1.765	1.374
h_j	0.294	0.157	0.145	0.088	0.051	0.094	0.096	0.075

In Table 3, bottom, ancillary expressions/data to be used in Chapter 4, are recorded. These mathematical expressions will be defined there.

3.2 Water management policies

In our context, this term is a comprehensive concept that refers to a set of measures to be applied potentially to the Júcar area. In what follows, they will be classified in groups and characterized. Not only do policies have to be defined but also the application framework must be known, i.e., if a given policy has been implemented before, where and how it has been applied, who makes the decision and what the role of farmers in the decision process is.

1. *Policies aimed at increasing water supply in the farming area.* Typical examples are desalination and interbasin water transfer, both included in the Delphi questionnaire. Regardless of the panellists' views, these policies will be commented next to gain insight into their characterization.
   (i) Desalination. In our context, this policy involves incentives to companies, which invest in desalination plants to convert Mediterranean seawater to fresh water suitable for irrigated farming. This policy has been already implemented in areas near the Júcar area, where several plants are currently working. In 2007, there were 25 plants in the Júcar basin area; however, only one of them supplies water for irrigation. This plant (El Campello) can supply 3900 m^3/day. Desalination can be criticized due to the following reasons: (a) it entails environmental damages because of energy consumption, carbon footprint and the fact that salt is dumped back into the sea at high temperatures; (b) piping and conveying large quantities of desalinated seawater into vast irrigated areas is costly today; (c) as a result, desalinated water should be traded at high prices, which is often inappropriate for irrigated farming (Downward and Taylor, 2007). Therefore, desalination involves a serious problem of sustainability. According to Alcolea et al. (2009), "it is generally more efficient and cheaper to desalt brackish groundwater from beach wells rather than desalting seawater". This policy requires approval by regional governments and local authorities. Sometimes, public financial support is granted by the government, but this is of little importance in terms of public expenditure. Farmers are not incorporated into the decision process.
   (ii) Interbasin water transfer. This policy can be either enforced by law or negotiated between stakeholders from the donor and the recipient basins (Ballestero, 2004). However, the Delphi questionnaire only refers to transfers enforced by law, because negotiated transfers have not been carried out in Spain yet. Some analyses estimate that desalination costs "are typically larger than the costs of transport. Indeed, one needs to lift the water by 2000 m, or transport it over more than 1600 km to get transport costs equal to the desalination costs" (Zhou and Toll, 2005). Nevertheless, comparisons between desalination and interbasin water transfer in terms of cost can lead to different results depending on regions. On the other hand, interbasin water transfers enforced by law have sparked controversy in Spain (see, e.g. Albiac et al., 2008). If massive amounts of transferred water are expected to cause significant impacts on the donor basin, then social acceptance will be even harder to reach. This policy has been locally considered and even implemented in the area through projects such as Júcar-Turia and Júcar-Vinalopó. A large interbasin water transfer has also been implemented between regions near the Júcar area such as the Tajo donor basin and the Segura recipient basin. Decisions on transfers enforced by law are obviously made by the government. Farmers are not incorporated into the decision process.
2. *Policies aimed at restricting water supply.* In the Delphi questionnaire, they are as follows.
   (i) Groundwater control. Currently, constructing and using wells for irrigation must be approved by the CHJ water agency. Despite this legal requirement, the number of wells has dramatically increased in some Júcar subareas, so that large groundwater extraction causes critical aquifer depletion. Groundwater control means not using more subsurface water than is recharged, which requires fewer extractions (Tobarra, 1996; Sahuquillo et al., 2005). According to the new Spanish law (Ley de Aguas, 1999), this control should

be enforced by installing water meters; however, this is not always applied in practice. This measure is costly and exposed to fraud. Sealing wells can be performed when extreme environmental damages appear, but this control requires starting proceedings or disciplinary actions against the farmer. This should be applied by local authorities, and especially by the public water agency. Experience in the Júcar area is rather limited. Together with individual water supply wells, which must have a permit from the CHJ water agency prior to installation, initiatives such as artificial recharge of flood waters are considered facets of groundwater control. Thus, the Spanish DINA-MAR project has determined the Spanish areas suitable for managed aquifer recharge (MAR). See http://www.dina-mar.es/. One of these areas is Júcar. So far, many MAR actions are developed by a public company (TRAGSA), but these companies are expected to be privatized. Farmers are not incorporated into the decision process.

(ii) Strict rationing of surface water to be allocated by public agencies to farmers. This policy is long-established in Spanish basins. Decisions are made by the public agency, taking prior rights into account. Farmers are not incorporated into the decision process.

(iii) Legal restrictions on irrigated land affecting some critical areas or crops (see Spanish Vineyard and Wine law, 2003). This means unpopular bans that may even cause social unrest. Moreover, bans can be virtually ignored by the farmers, and then, implementing the measure becomes problematic. This policy has been experienced in Spain (e.g. vineyard), but in a limited way. Decisions are typically made by the government. They may require approval by the regional Parliament. Farmers are not incorporated into the decision process.

3. *Policies aimed at allocating irrigation water efficiently in the area.* In economics, efficiency of competitive markets versus inefficiency of the other ways of resource allocation is proven (see, e.g., Borenstein, 1988). In the Delphi questionnaire, these policies are: (i) establishing irrigation water markets and water banks; (ii) reallocating public water concessions, which involves allocating less surface water to prior rights farmers at low prices, and supplying surface water to farmers at higher prices (Ballestero et al., 2002; Thoyer, 2006). In the Delphi survey, the phrase “higher water prices” means prices close to market prices in the area. Since 1999, the Spanish law has changed in order to allow farmers to sell their prior rights on the market. To encourage this policy, the Water Use Rights Exchange Centres are established and managed by the central government. Currently, there are centres in the Guadiana, Júcar and Segura basin areas (Milla, 2005). Spanish government plans are underway to establish water banks, as is the case in California and other regions.
4. *Policies that combine some of the goals described above.* In Table 3, the complete list of twenty policies proposed in the Delphi questionnaire is displayed (row headings). This list has been decided by the analysts (authors of this paper) taking into account opinions of experts, who cooperate with the Spanish CHJ water agency. Of the 20 policies, 10 are pure policies while the other 10 are combined policies.

In many of the above policies, notice that farmers are not incorporated into the decision process. (a) Concerning decisions on investing in water supply infrastructure, they are typically made either by private companies or by government agencies. Indeed, both companies and agencies sound out opinions of farmers from around the country/area either for marketing purposes or for political purposes. (b) Concerning water control and surface water supply restrictions in Spain, they are policies decided and implemented by government agencies as farmers are generally against them.

Finally, the financial impact of these policies will be examined. (a) As noted, subsidies (if any) to desalination plants are relatively small. (b) Under new regulations in Spain, infrastructure such as interbasin water transfers and others are financed by methods like Project Finance (private initiative with some government guarantees), so that the public expenditure is not significantly affected. (c) As to the other policies, the water users pay for them through taxes and prices.

3.3 Criteria

Each policy is evaluated by each Delphi panellist from 8 criteria, labelled and defined as follows.

1. *Technical viability (C1).* Concerning a water policy, technical viability is the ability of technological success with continued effectiveness.
2. *Economic viability (C2).* Concerning the problem of implementing a given water policy by public agencies or institutions, economic viability is the ability of benefits to cover implementation costs. Both public and private benefits should be considered here. For the purpose of the Delphi survey, the above informal definition can be more appropriate than a strict academic definition, as the Delphi panellists are practitioners rather than scientists (see Chapter 1).
3. *Environmental impact (C3).* In broad terms, environmental impact refers to the damaging effects of a water policy, now and in the future, not only on ecosystems, but also on health, security, well being, social and economic development, landscape, and natural resources.
4. *Social acceptance (C4).* In our context, social acceptance especially refers to community acceptance. This means the extent to which local stakeholders (authorities, farmers, entrepreneurs, workers, and broadly speaking, residents in the area) are in favour of or against the water policy under consideration. A range of social impacts (e.g. labour) are here considered.
5. *Interregional conflicts (C5).* Social groups in a region X can fear that a given water policy intended for another region Y may harm economic/environmental interests in X. Then, unrest/agitation will arise in region X.
6. *Compliance with European, Spanish and regional regulations (C6, C7 and C8, respectively).* These three criteria describe to what extent a given water policy fulfils European, Spanish and regional legal requirements, which might be potentially modified.

In Table 3, these 8 criteria are displayed (column headings).

4. RANKING THE POLICIES FROM THE DELPHI SURVEY

Hereafter, objective 1.2 in Chapter 1 will be addressed. This means evaluating each policy from an aggregation of criteria, namely, from the set of 8 criteria as a whole. For this purpose, the COBB method is applied, which requires the following steps.

4.1 Criteria ordering

A preference ordering of criteria C_j (j= 1, 2, …, 8) is established by the analyst taking the relative importance of each criterion into account, namely:

$$C_1 \approx C_2 \approx C_3 \succ C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8 \qquad (1)$$

Ordering (1) appears appropriate. Indeed, technological viability, economic viability and environmental impact seem to be more important than the other criteria; however, one cannot say which of the three C_1, C_2 and C_3 should be considered as the most significant or the second most significant. Therefore, Laplace principle of insufficient reason advises to consider all three as equally preferred. Concerning the other criteria, say, social acceptance, interregional conflicts, and compliance with European, Spanish and regional regulations, all five seem to be of similar importance. In Chapter 5, some orderings other than (1) will be used to find different rankings from a sensitivity analysis.

4.2 Ranking indexes

A ranking index for each *i*th policy is given by the Cobb-Douglas function:

$$R_i = \prod_{j=1}^{j=8} v_{ij}^{h_j} \; ; \; h_j > 0 \text{ for all } j \text{ with } \sum_{j=1}^{j=8} h_j = 1 \tag{2}$$

where R_i is the *i*th policy ranking index (*i*= 1, 2, …, 20) while v_{ij} is the mean value of the panellists' evaluations about the *i*th policy from the *j*th criterion. In Table 3, the v_{ij} mean values are recorded.

The Cobb-Douglas function is a classic power function of multiple attributes and constant elasticity, with a long history in management and social sciences (Lloyd, 2001). It proves superior to linear indexes, especially because Cobb-Douglas more realistically explains changes in the output caused by changes in the inputs. Indeed, from experience in different fields, we usually observe that relative (percentage) changes in the *j*th input often produce relative proportional changes in the output, other things being equal. This is just what Cobb-Douglas function states. In fact, from equation (2), we have:

$$dR / R = h_j dv_j / v_j \tag{3}$$

Thus, equation (3) states proportionality in relative terms, namely, percentage increase dR/R is assumed to be proportional to percentage increase dv_j / v_j, other things being equal.

4.3 Estimating parameters of index (2) by the COBB method

In this method, parameters h_j are estimated from ordering (1) by resorting to Laplace principle of insufficient reason. General estimates are given in Ballestero (2006). In our special case, they become:

$$h_j = \alpha_j \Big/ \sum_{j=1}^{j=8} \alpha_j \tag{4}$$

$$\alpha_j = 2/(\log v_{j\max} - \log v_{j\min}) \text{ if } j= 1, 2, 3 \tag{5}$$

$$\alpha_j = 1/(\log v_{j\max} - \log v_{j\min}) \text{ if } j= 3, 4, \ldots, 8 \tag{6}$$

where $v_{j\max}$ and $v_{j\min}$ are, respectively, the highest and lowest values in the *j*th column of Table 3, while symbol "log" means natural logarithm.

4.4 Computation and results

In Table 3, bottom, the ancillary expressions $\log v_{j\max}$, $\log v_{j\min}$ and $(\log v_{j\max} - \log v_{j\min})$ are recorded for each *j*th column. By substituting these numerical values for $(\log v_{j\max} - \log v_{j\min})$ in equations (5)-(6), we obtain the α_j values, which are displayed at the bottom of the table. These α_j values are now introduced into equation (4) to obtain the h_j parameters, which also appear in Table 3, last row. Therefore, equation (2) turns into:

$$R_i = v_{i1}^{0.294} v_{i2}^{0.157} v_{i3}^{0.145} v_{i4}^{0.088} v_{i5}^{0.051} v_{i6}^{0.094} v_{i7}^{0.096} v_{i8}^{0.075} \quad (7)$$

Equation (7) yields the ranking index R_i for the *i*th policy (*i*= 1, 2, …, 20). To compute each of them, every v_{ij} mean value of the panellists' evaluations about the *i*th policy from the *j*th criterion is introduced into equation (7). For example, for *i*=2, the ranking index is:

$$R_2 = 3.000^{0.294} * 3.111^{0.157} * 2.778^{0.145} * 3.000^{0.088} * 3.333^{0.051} * 3.333^{0.094} * 3.889^{0.096} * 2.778^{0.075} = 3.088$$

In Table 4, the policy ranking from ordering (1) is shown with the corresponding indexes. At the top of the ranking, we find the policy of "desalination combined with higher water prices and even with interbasin water transfer". As the second best, the policy of "groundwater control combined with interbasin water transfer" is found. The third best is "groundwater control", and the fourth is "irrigation water markets/water banks combined with higher water prices even paid by prior rights farmers". At the bottom of the ranking, we have "interbasin water transfer" while the penultimate is "higher water prices", both being pure policies.

Table 4. Ranking indexes from Table 3

Pure policies	Ranking index	Combined policies	Ranking index
IWT	2.287	IWT with HWP	2.788
DES	3.088	DES with HWP and IWT	3.388
IWM	2.701	IWM with HWP-PRF	2.975
IWM/WB	2.941	IWM/WB with HWP-PRF	3.142
GC	3.150	GC with IWT	3.383
LSWF	2.659	LSWF with IWM	2.894
HWP	2.429	HWP with IWM/WB	2.670
HWP-PRF	2.529	HWP-PRF with IWM/WB	2.716
IRC	2.503	IRC with LSWF	2.747
IRA	2.502	IRA with LSWF	2.778

5. SENSITIVITY ANALYSIS, SHARPE-BASED EVALUATION AND RESULTS

To gain insight into Chapter 4, two critical issues such as sensitivity analysis and Sharpe-based evaluation are undertaken next.

5.1 Sensitivity analysis

This is developed by comparing the ranking obtained from ordering (1) to rankings from other orderings. Consider the following possible orderings.

(i) $C_1 \approx C_2 \approx C_3 \succ C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$, namely, ordering (1).

(ii) $C_1 \approx C_2 \approx C_3 \approx C_4 \approx C_5 \succ C_6 \approx C_7 \approx C_8$

(iii) $C_1 \approx C_2 \approx C_3 \approx C_6 \approx C_7 \approx C_8 \succ C_4 \approx C_5$

(iv) $C_1 \approx C_2 \approx C_3 \approx C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$

(v) $C_1 \approx C_2 \succ C_3 \approx C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$

(vi) $C_1 \approx C_2 \approx C_3 \approx C_4 \succ C_5 \approx C_6 \approx C_7 \approx C_8$

What if ordering (i) was replaced by each of the remaining five? Then, we would obtain six rankings (including the previous one), which are shown in Table 5, columns 1-6. Correlations between the above rankings are found by computing the correlation coefficient between each pair of the corresponding ranking indexes (see Table 6). These coefficients range between 0.983 and 0.998, so that correlation is very high.

5.2 Ranking from the Sharpe performance ratio

In Chapter 4, the ranking of policies was established from the Delphi survey by using mean values of the panellists' evaluations as a straightforward way of aggregating the panellists' opinions. However, this way of aggregating has an inconvenience, namely, dispersion of opinions is not considered. To avoid this drawback, the Sharpe performance ratio can be used instead of mean value. In our context and with our notation, the Sharpe ratio is defined as follows:

$$S_{ij} = v_{ij} / \sigma_{ij} \text{ , or alternatively, } \sqrt{v_{ij} / \sigma_{ij}} \quad (8)$$

for every *i*, *j*, where σ_{ij} is the standard deviation of the panellists' opinions about the *i*th policy from the *j*th criterion. This ratio has a clear meaning: average per unit of variability (Sharpe, 1997). Now, the new ranking for each criteria ordering is computed by equation (7) where every v_{ij} is replaced by the corresponding Sharpe ratio (8). As a result, Sharpe-based rankings from orderings (i) and (iv) are displayed in Table 5, columns 7 and 8, respectively. Correlation between ranking 7 and its corresponding ranking 1 (the latter obtained from mean values) is 0.952. An even higher correlation of 0.987 is found between ranking 8 and its corresponding ranking 4. These significant correlations suggest that aggregating either by mean values or by Sharpe performance ratios leads to similar results.

5.3 Summarising the results

(a) Generally, the pure policies have been evaluated lower than the combined policies by the Delphi panel. Thus, in four rankings, 3 pure policies and 7 combined ones appear among the top ten policies, while in the remaining four rankings, 4 pure policies and 6 combined ones are in the top ten. (b) In the six rankings determined by aggregating mean values of Delphi opinions (Table 5, columns 1-6), the best policy is "desalination combined with higher water prices and with interbasin water transfer" while the second best is "groundwater control combined with interbasin water transfer". (c) In the two rankings determined by aggregating Sharpe performance ratios (Table 5, columns 7-8), the best policy coincides with the second best in case (b). Concerning the second best with Sharpe performance ratios, it is "irrigation water markets/water banks combined with higher water prices even paid by prior rights farmers". This policy ranks third/fourth in rankings 1-6. (d) At the bottom of the 8 rankings (last three positions), the worst evaluated policies are "irrigation restrictions on some crops/areas" (eleven times), "interbasin water transfer" (eight times), and "higher water prices" (five times), all of them being pure policies. (e) Notice that interbasin water transfer ranks low as a pure policy, namely, as a policy to be applied alone; however, it ranks high as a combined policy, namely, as a policy to be applied in conjunction with other measures.

6. CONCLUSION

Finally, the value added by this research is stated as follows.

(i) Our case study refers to a European basin of economic relevance with water deficits. To mitigate this problem, the policies to be established should be not only scientifically correct but also politically acceptable. There are approaches to the Júcar area and other Mediterranean basins in which the water policies are evaluated from the scientific perspective of the analyst but there is little available information on the institutional stakeholders' views concerning such policies. This paper provides this information as a useful complement to the other perspectives.

Table 5. Policy rankings for different criteria orderings

Using mean values of panellists' evaluations						Using Sharpe ratios from panellists' evaluations	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
DES with HWP and with IWT	DES with HWP and IWT	DES with HWP and IWT	DES with HWP and IWT	DES with HWP and IWT	DES with HWP and IWT	GC with IWT	GC with IWT
GC with IWT	GC with IWT	GC with IWT	GC with IWT	GC with IWT	GC with IWT	IWM/WB with HWP-PRF	IWM/WB with HWP-PRF
GC	IWM/WB with HWP-PRF	DES	DES	GC	IWM/WB with HWP-PRF	GC	DES with HWP and IWT
IWM/WB with HWP-PRF	DES	IWM/WB with HWP-PRF	IWM/WB with HWP-PRF	IWM/WB with HWP-PRF	GC	IWM with HWP-PRF	IWM with HWP-PRF
DES	GC	GC	GC	DES	DES	DES with HWP and IWT	GC
IWM with HWP-PRF	IWM with HWP-PRF	IWM with HWP-PRF	IWM with HWP-PRF	IWM with HWP-PRF	IWM with HWP-PRF	IWM/WB	IWM/WB
IWM/WB	IWM/WB	IWM/WB	IWM/WB	IWM/WB	IWM/WB	IWT with HWP	IWT with HWP
LSWF with IWM	LSWF with IWM	LSWF with IWM	LSWF with IWM	LSWF with IWM	LSWF with IWM	LSWF with IWM	DES
IWT with HWP	IWT with HWP	IWT with HWP	IWT with HWP	IWT with HWP	IWT with HWP	DES	LSWF with IWM
IRA with LSWF	IRA with LSWF	IWM	IWM	IRA with LSWF	IRA with LSWF	IWM	IWM
IRC with LSWF	IWM	HWP-PRF with IWM/WB	IRA with LSWF	IRC with LSWF	IWM	LSWF	LSWF
HWP-PRF with IWM/WB	IRC with LSWF	IRA with LSWF	HWP-PRF with IWM/WB	HWP-PRF with IWM/WB	IRC with LSWF	HWP-PRF with IWM/WB	HWP-PRF with IWM/WB
IWM	HWP-PRF with IWM/WB	HWP with IWM/WB	HWP with IWM/WB	IWM	HWP-PRF with IWM/WB	HWP	HWP
HWP with IWM/WB	HWP with IWM/WB	IRC with LSWF	IRC with LSWF	LSWF	HWP with IWM/WB	HWP-PRF	HWP with IWM/WB
LSWF	LSWF	LSWF	LSWF	HWP with IWM/WB	LSWF	HWP with IWM/WB	HWP-PRF
HWP-PRF	HWP-PRF	HWP-PRF	HWP-PRF	HWP-PRF	IRA	IRC with LSWF	IRC with LSWF
IRC	IRA	HWP	IRA	IRC	HWP-PRF	IRA with LSWF	IRA with LSWF
IRA	IRC	IRA	HWP	IRA	IRC	IRA	IWT
HWP	HWP	IRC	IRC	HWP	HWP	IRC	IRA
IWT	IWT	IWT	IWT	IWT	IWT	IWT	IRC

Column description (criteria ordering under consideration):

1. $C_1 \approx C_2 \approx C_3 \succ C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$
2. $C_1 \approx C_2 \approx C_3 \approx C_4 \approx C_5 \succ C_6 \approx C_7 \approx C_8$
3. $C_1 \approx C_2 \approx C_3 \approx C_6 \approx C_7 \approx C_8 \succ C_4 \approx C_5$
4. $C_1 \approx C_2 \approx C_3 \approx C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$
5. $C_1 \approx C_2 \succ C_3 \approx C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$
6. $C_1 \approx C_2 \approx C_3 \approx C_4 \succ C_5 \approx C_6 \approx C_7 \approx C_8$
7. $C_1 \approx C_2 \approx C_3 \succ C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$
8. $C_1 \approx C_2 \approx C_3 \approx C_4 \approx C_5 \approx C_6 \approx C_7 \approx C_8$

Table 6. Correlations between rankings from criteria orderings 1-6 in Table 5

	1	2	3	4	5	6
1	1	0.994	0.990	0.983	0.997	0.995
2	0.994	1	0.992	0.994	0.995	0.998
3	0.990	0.992	1	0.997	0.990	0.990
4	0.983	0.994	0.997	1	0.986	0.990
5	0.997	0.995	0.990	0.986	1	0.997
6	0.995	0.998	0.990	0.990	0.997	1

(ii) Proposing new methodologies is not an objective of case studies; however, we have used a new modality of Delphi survey in which evaluations are aggregated by multiple criteria decision making analysis. This is relevant as the method allows the panellist to give multiple assessments for each policy.

Future research could be conducted as follows: (a) to review literature on water use planning to compare policy rankings from other authors to the political ranking in this paper; (b) to extend similar Delphi surveys to other Mediterranean regions.

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