Water Resources and Economics 42 (2023) 100219

Contents lists available at ScienceDirect

Water Resources and Economics

journal homepage: www.elsevier.com/locate/wre

Heterogeneity in the WTA-WTP disparity for irrigation water reliability

Anastasio J. Villanueva [a,b], José A. Gómez-Limón [b,*]

[a] Dpt. of Agri-Food Economics, Institute of Agricultural and Fisheries Research and Training, IFAPA Camino de Purchil s/n, PO Box: 2027, E-18004, Granada, Spain

[b] WEARE-Water, Environmental and Agricultural Resources Economics Research Group, Universidad de Córdoba, Puerta Nueva s/n, E-14071, Córdoba, Spain

ARTICLE INFO

Handling Editor: Erik Ansink

Keywords:
Water supply guarantee
Water policy
Climate change
Loss aversion
Choice experiment

ABSTRACT

This paper assesses the WTP and WTA for improvements and deteriorations, respectively, in irrigation water supply reliability. The assessment relies on a double-sided discrete choice experiment valuation using latent-class modeling accounting for preference and scale heterogeneity. This valuation approach is empirically implemented using a case study of a Spanish irrigated district significantly impacted by climate change. The results obtained show individual-specific preference heterogeneity in the WTA-WTP disparity, primarily driven by the different impacts of water reliability on farmers' utility (changes in business revenues and costs, uncertainty in business performance, and farm income effects) and interindividual differences in loss aversion (different degrees of endowment effect). Additionally, the significant scale heterogeneity and ordering effects found suggest that it may be advisable to use modeling approaches that account for them. Several policy-relevant implications can be drawn, including the non-neutrality of the initial allocation of property rights, repercussions on the cost-benefit of climate change adaptation measures, and the need to account for irrigators' preference heterogeneity in order to design successful market-based instruments.

1. Introduction

The most recent projections for Mediterranean semi-arid regions indicate a progressive rise in the average temperature, a decrease in precipitation, and an increase in the frequency and length of extreme drought events [1]. These changes in climate parameters are already being felt by farmers, prompting them to implement several adaptive strategies [2].

As the main water users in these regions, irrigators are deeply concerned since climate change is already causing an increase in irrigation water needs (higher crop evapotranspiration rates due to rising temperatures) and a reduction in water availability, both structurally (shortages in average rainfall and water inflows feeding irrigation systems) and cyclically (more frequent and acute drought episodes) [3]. The combination of these two circumstances adversely affects irrigation water supply reliability, seriously jeopardizing the economic sustainability of the irrigators' farms (lower, more volatile income because of smaller, more uncertain crop yields).

In order to deal with this situation, two different policy approaches can be considered to maintain or improve irrigation water

* Corresponding author.
E-mail address: jglimon@uco.es (J.A. Gómez-Limón).

https://doi.org/10.1016/j.wre.2023.100219
Received 5 March 2022; Received in revised form 18 January 2023; Accepted 20 February 2023
Available online 24 February 2023

supply reliability. The first approach, known as supply-side water policy, is focused on increasing water availability by building new reservoirs and other water infrastructure. This approach was traditionally implemented during the 20th century [4]. However, it is no longer an option in more developed regions since new increases in water availability are technically and environmentally infeasible or economically unaffordable [5]. In these cases, the only possible approach is demand-side policy, which optimizes the management of currently available water resources by improving water-use efficiency and reducing the irrigators' exposure to water availability risk. This type of policy instrument includes the modernization of irrigation systems, water pricing, water markets, and water banks [6].

To efficiently design demand-side water management instruments, information is needed on water users' welfare change associated with improvements in water supply reliability (i.e., for those benefiting from the implementation of policy instruments) and deteriorations (i.e., for those whose supply reliability is reduced). However, there is scarce literature in this field regarding irrigated agriculture. To the authors' knowledge, Rigby et al. [7], Mesa-Jurado et al. [8], Bell et al. [9], Alcón et al. [10], and Guerrero-Baena et al. [11] represent the few studies that assess irrigation water supply reliability. All these studies measure irrigators' welfare change in terms of willingness to pay (WTP) for improvements in water supply reliability, in line with official recommendations from the NOAA panel on contingent valuation, which state that benefit-cost analyses should be based on WTP [12]. However, more recent literature suggests that the use of WTP measures for the valuation of deteriorations in water supply reliability (i.e., damages) may underestimate the economic value of welfare changes, thus leading to suboptimal policy design [13,14]. All this evidence calls for the use of WTA formats (rather than WTP) to estimate the welfare changes associated with the progressive deterioration of water supply reliability due to either climate change in a no-policy scenario or the implementation of demand-side instruments. Nevertheless, such a valuation approach has yet to be implemented, and no reliable value estimation of declines in reliability is available in the existing literature.

Within this framework, the paper's primary objective is to analyze the disparity between the WTP for improved irrigation water supply reliability and the WTA for compensation for deterioration in water supply reliability. While a large body of literature provides empirical evidence of the WTA-WTP disparity [15,16], including a substantial number of papers focusing on ordinary private goods and environmental public goods, no study has previously estimated such a disparity focusing on a singular good such as irrigation water, a common-pool resource which is used as a business input. Such a double-sided valuation will allow us to provide new insights into the disparity between WTP and WTA and the heterogeneity of said disparity, opening up a discussion on the reasons behind this gap and drawing relevant policy implications for implementing demand-side approaches.

For this purpose, this paper relies on an economic experiment with farmers in an irrigated area in the Guadalquivir River Basin (southern Spain) that is suffering a severe deterioration in water supply reliability because of climate change and increasing demand for water for other economic and environmental uses (more stringent requirements for ecological streamflows) [17]. A choice experiment (CE) application is employed to assess WTP and WTA for improvements and deteriorations in irrigation water supply reliability, respectively, for a representative sample of irrigators. Additionally, a latent class modeling approach accounting for preference and scale heterogeneity is used for the first time with farmers.

2. The WTA-WTP disparity regarding irrigation water supply reliability

The disparity between WTA and WTP is one of the most extensively-documented phenomena in the literature dealing with economic valuation, with many empirical studies reporting evidence that WTA values tend to be substantially higher than WTP values. In their reviews of the literature, Horowitz and McConnell [18] find substantial heterogeneity among case studies in terms of the WTA/WTP ratio, and a mean WTA/WTP ratio of approximately 7. In a more recent meta-analysis, Tunçel and Hammitt [16] report a mean value above 3.

Although the disparity between WTA and WTP related to irrigation water supply reliability has not been studied yet, there are a few studies showing a significant WTA-WTP gap regarding other water services: Del Saz-Salazar et al. [19] focused on improvements in water quality of a river; Lanz et al. [20] and MacDonald et al. [21] studied the quality of the services provided by urban water supply companies; Giannoccaro et al. [22] analyzed farmers' willingness to buy and to sell water through a seasonal market; and Koetse and Brouwer [14] valued changes in flood control. All this suggests that there may also be a disparity in WTA and WTP values for irrigation water supply reliability.

Considering neoclassical economic theory (Hicksian welfare theory), Kim et al. [13] suggest various theoretical justifications for differences or asymmetries between WTA and WTP: income effect, substitution effect, profit-seeking behavior, and transaction costs. Indeed, these are plausible reasons for the WTA-WTP disparity in valuation contexts focusing on irrigation water supply reliability.

However, there is a broad consensus that the degree of WTA-WTP asymmetry observed in empirical studies cannot be reasonably explained purely by the traditional economic reasons pointed out above, and that individuals' psychological and behavioral patterns also play a relevant role [18]. Knetsch [23] was the first to explain the asymmetry of WTA-WTP as evidence of the 'endowment effect', a manifestation of 'loss aversion' [24], which refers to the notion that people value losses higher than gains; that is, they usually require more compensation (WTA) to give up a good that they already possess than they would pay to obtain another similar one (WTP). This intuition was confirmed by Kahneman et al. [25], who interpreted Knetsch's results as support for prospect theory. This interpretation has been expanded in a large and growing literature [14]. Since loss aversion has already been demonstrated among farmers worldwide [e.g., 26,27], it may influence the WTA-WTP disparity in a valuation exercise focusing on irrigation water reliability.

Finally, it has also been suggested that the WTA-WTP gap could be an artifact caused by inaccurate elicitation techniques and poor experimental designs. In this respect, the literature identifies two main reasons related to hypothetical bias and other features of the valuation context (different framing for WTP and WTA, time issues, sequence bias, policy program definition, etc.) [16,28,29]. However, though hypothetical and other biases may be relevant when analyzing farmers' preferences toward policy options [30], a careful experimental design aimed at enhancing survey consequentiality (e.g., by collaborating with management agencies and institutions and informing participants about how results will support their decision-making) and minimizing hypothetical bias (e.g., using 'cheap talk') [31,32] can largely preclude significant biases related to the elicitation techniques.

3. Case study: the Santaella irrigators' community

3.1. Santaella irrigators' community

Since the Water Act of 1985 entered into force, all water resources in Spain have been officially declared public property governed by public basin agencies. This legislation also stipulates that any private use (e.g., irrigation) has to be approved by the State through legal authorizations. When these water rights are granted, users are allocated a maximum annual amount of water (water concession) for uses defined explicitly in the associated legal document. However, the amount of water actually provided each year (water allotments) can be lower than water concessions since the Spanish public basin agencies have the legal capacity to enforce restrictions depending on the level of water stored in reservoirs.

The Santaella Irrigators' Community (IC), located in the Guadalquivir River Basin (GRB) in southern Spain, has been selected as a case study. This IC is a large irrigation district (15,500 ha) using surface water resources delivered by the GRB agency. Like many other ICs in the basin, Santaella IC was established at the end of the 20th century, but currently operates with modern, efficient irrigation technologies, most commonly sprinkler and drip irrigation systems [33]. The main crops are olive, cotton, wheat, vegetables (mainly garlic and onion), and sunflower. The water fees paid by irrigators are calculated based on fixed costs, primarily covering depreciation and maintenance of infrastructures as well as personnel requirements, and variable costs, mainly covering energy consumed for pumping in the provision of water services. Irrigators are charged separately for these costs through a two-part bill, including one component based on the criterion of area (a charge for fixed costs of approximately €150/ha/year on average) and one volumetric component (a charge for variable costs of €0.04/m^3/year on average).

Like most of the ICs in the GRB, Santaella IC typically receives water allotments lower than the legal concession of 5000 m^3/ha/year to which it is entitled. Indeed, the average water use in the last 20 irrigation seasons has been 2572 m^3/ha/year (51% of the water concession), confirming that water supply reliability is relatively low. Water allotment can be considered a stochastic variable with its own probability density function (PDF) and cumulative distribution function (CDF). Data on Santaella IC's yearly water allotments of the past 20 years fit several possible distribution functions, with the normal distribution function turning out to be one of the most accurate for representing the variability in water supply [11]. Fig. 1 shows the normal PDF and CDF for these data, displaying the two parameters that characterize the PDF, i.e., parameters μ (mean) and σ^2 (variance). This normal PDF represents the reference for the two valuation exercises performed (i.e., CE_WTP and CE_WTA), as it is already well known by all the irrigators operating in the Santaella IC.

3.2. Setting the valuation scenarios

Three scenarios of better water supply reliability were proposed (scenarios B1, B2, and B3), representing reductions in the annual gap or difference between concession and allotment of 25%, 50%, and 75%, respectively. Furthermore, two scenarios of worse water supply reliability were also proposed (scenarios W1 and W2), representing increases in the annual concession-allotment gap of 25% and 50%, respectively. Based on these scenarios, modified yearly water allotments were calculated for each case in the Santaella IC for the last 20 irrigation seasons. These modified series of yearly water allotments were used to fit five distribution functions describing the variability in water allotments under each scenario. All these fits were consistent with normal distribution functions, as confirmed by the A-D statistical test.

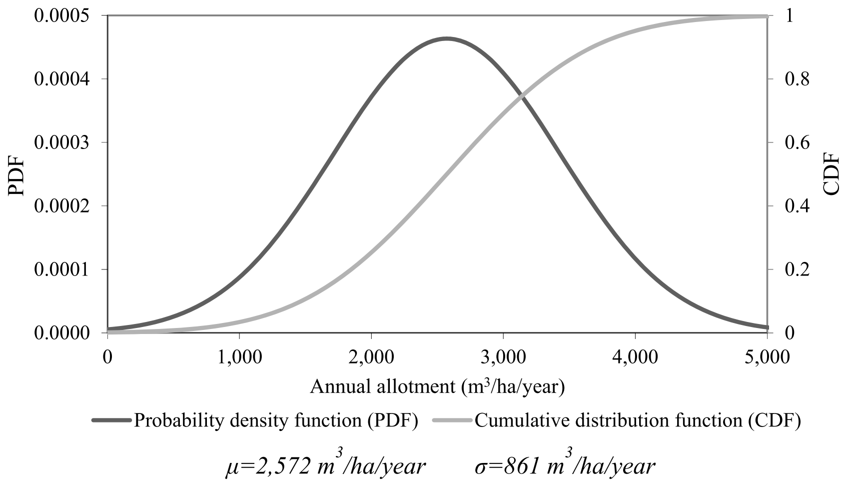


Fig. 1. Normal PDF and normal CDF in Santaella IC (status quo scenario).

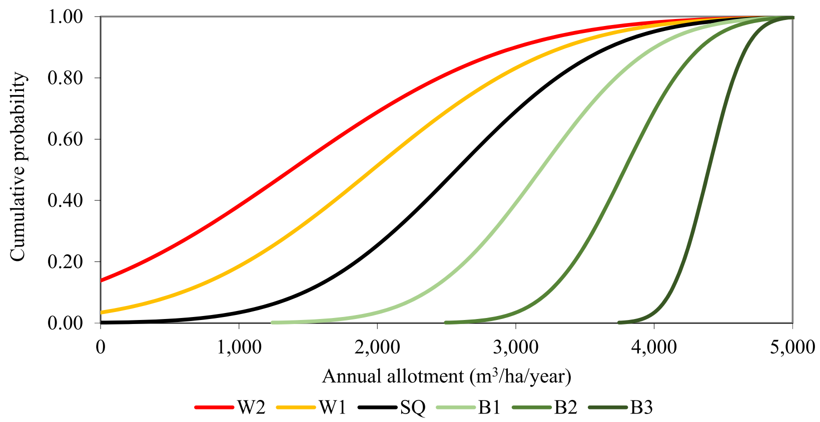


Fig. 2. Normal CDFs in the Santaella IC for the water reliability scenarios: status quo (*SQ*), *B1* (gap −25%), B2 (gap −50%), *B3* (gap −75%), *W1* (gap +25%), and *W2* (gap +50%).

Table 1
Normal distribution parameters for the water reliability scenarios considered in Santaella IC.

Parameters	Status quo (*SQ*) scenario	Better scenarios			Worse scenarios	
		B1 (gap −25%)	*B2* (gap −50%)	*B3* (gap −75%)	*W1* (gap +25%)	*W2* (gap +50%)
μ (m^3/ha/year)	2572	3179	3786	4393	1965	1378
σ^2 (m^3/ha/year)^2	741,321	417,316	185,761	46,225	1,158,637	1,604,782
P05 (m^3/ha/year)	1155	2117	3078	4039	194	0
P25 (m^3/ha/year)	1991	2743	3495	4248	1238	524
P50 (m^3/ha/year)	2572	3179	3786	4393	1965	1378

Note: P05, P25, and P50 denote 5th, 25th, and 50th percentiles.

The resulting PDFs and CDFs allowed us to focus our analysis on irrigators' WTP for better water supply reliability (distribution functions describing scenarios B1, B2, and B3) and WTA for worse water supply reliability (distribution functions describing scenarios W1 and W2). Fig. 2 shows the resulting CDFs for the five scenarios considered, while Table 1 shows μ and σ^2 parameters of the normal distribution functions fitted for each scenario (with 5th, 25th, and 50th percentiles, also provided).

4. Methodological approach

4.1. Choice experiment approach

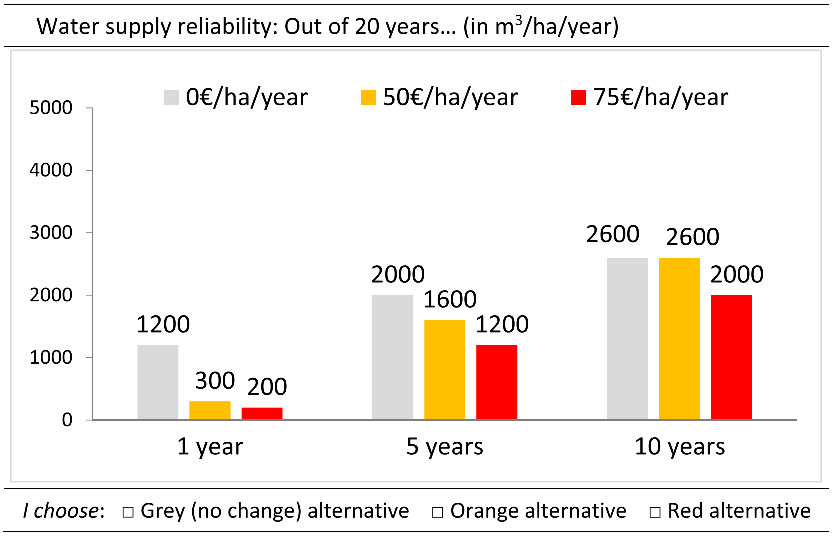
The CE method is a stated preference valuation technique based on the Lancasterian consumer theory of utility maximization, with the econometric basis of the approach underpinned by random utility theory. Hensher et al. [34] provide a comprehensive theoretical and practical explanation of the CE method. The widespread use of CE, both in general [31,32] and in particular with irrigators [7,9,10], indicates its suitability for analyzing irrigators' utility changes for variations in water supply reliability.

Two consecutive CE exercises were administered to each interviewee: one focused on WTP for better water supply reliability (CE_WTP) and the other on WTA for worse water supply reliability (CE_WTA). Both exercises used the same attributes: two non-monetary attributes related to the normal PDF describing water supply reliability –μ and σ^2 parameters–and one monetary attribute. The definition of the non-monetary attributes relied on a mean-variance approach, as justified in Guerrero-Baena et al. [11], representing possible changes in the PDF for water supply reliability in the irrigated area. For this purpose, the attribute levels considered were linked to the changes relating to the abovementioned scenarios of better and worse water supply reliability. Thus, for the attribute related to μ, the levels were μ_{SQ}, μ_{B1}, μ_{B2}, and μ_{B3} for CE_WTP, and μ_{SQ}, μ_{W1}, and μ_{W2} for CE_WTA. The levels of the attribute σ^2 were σ^2_{SQ}, σ^2_{B1}, σ^2_{B2}, and σ^2_{B3} for CE_WTP, and σ^2_{SQ}, σ^2_{W1}, and σ^2_{W2} for CE_WTA. Table 2 shows the attributes and levels used for the two CE exercises.

The monetary attribute (EUR) consisted of an additional yearly payment to improve irrigation water supply reliability and an annual monetary compensation to be received in exchange for accepting worse reliability. The monetary attribute levels were defined relative to current expenses for irrigation water, using the following six levels: 2%, 5%, 10%, 20%, 30%, and 50% of the average farmer's total irrigation water expenses (€255/ha/year). These levels corresponded to the following absolute values (rounded figures): €5, €10, €25, €50, €75, and €125 per hectare and year, indicating the money paid and received in the case of CE_WTP and CE_WTA, respectively.

Table 2
Attributes and levels used in the choice experiments.

Attribute	Explanation	Levels	
		CE exercise focusing on WTP for better scenarios (CE_WTP)	CE exercise focusing on WTA for worse scenarios (CE_WTA)
μ parameter	μ parameter of the normal PDF fitting the six scenarios considered for water supply reliability of the irrigation district	$\mu_{SQ} = 2,572; \mu_{B1} = 3,179; \mu_{B2} = 3,786; \mu_{B3} = 4,393$ (m^3/ha/year) (i.e., μ parameter of the normal PDF of the situation where the gap between the allotments and the concession is reduced by 25%, 50%, and 75%, for the better scenarios respectively)	$\mu_{SQ} = 2,572; \mu_{W1} = 1,965; \mu_{W2} = 1,378$ (m^3/ha/year) (i.e., μ parameter of the normal PDF of the situation where the gap between the allotments and the concession is increased by 25% and 50%, for the worse scenarios respectively)
σ^2 parameter	σ^2 parameter of the normal PDF fitting the six scenarios considered for water supply reliability of the irrigation district	$\sigma^2_{SQ} = 741,321$; $\sigma^2_{B1} = 417,316$; $\sigma^2_{B2} = 185,761$; $\sigma^2_{B3} = 46,225$ ((m^3/ha/year)^2) (i.e., σ^2 parameter of the normal PDF of the situation where the gap between the allotments and the concession is reduced by 25%, 50%, and 75%, for the better scenarios respectively)	$\sigma^2_{SQ} = 741,321$; $\sigma^2_{W1} = 1,158,637$; $\sigma^2_{W2} = 1,604,782$ ((m^3/ha/year)^2) (i.e., σ^2 parameter of the normal PDF of the situation where the gap between the allotments and the concession is increased by 25% and 50%, for the worse scenarios respectively)
Monetary attribute (*EUR*)	Yearly additional payment to improve water supply reliability paid by the farmer	2%, 5%, 10%, 20%, 30%, and 50% (€/ha/year) of current total payment for irrigation water to pay for better reliability	2%, 5%, 10%, 20%, 30%, and 50% (€/ha/year) of current total payment for irrigation water to be received in exchange for worse reliability



Note: *Grey (no change) alternative*=(μ_{SQ}; $\sigma^2{}_{SQ}$; €0); *Orange alternative*=(μ_{SQ}; $\sigma^2{}_{W1}$; €50); *Red alternative*=(μ_{W1}; $\sigma^2{}_{W1}$; €75).

Fig. 3. Example of a choice card. CE exercise focusing on WTA (translated to English).
Note: *Grey (no change) alternative*=(μ_{SQ}; σ^2_{SQ}; €0); *Orange alternative*=(μ_{SQ}; σ^2_{W1}; €50); *Red alternative*=(μ_{W1}; σ^2_{W1}; €75). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

To provide a meaningful valuation context to the farmers, since the parameterization of the normal PDF is meaningless for them (mainly the attribute σ^2*)*, the combinations of the levels of the attributes μ and σ^2 that characterize the changes proposed for each alternative water supply reliability were shown through three points of the resulting CDF corresponding to the 5th, 25th, and 50th percentiles (corresponding to 1, 5, and 10 years out of the 20-year period). In this way, farmers understood the different degrees of irrigation water supply reliability reflected by each combination of attribute levels.

As for the status quo and the scenarios of better/worse water supply reliability (see Section 3.2), normal PDFs were assumed to represent the water supply probability functions for the combinations of the levels of the attributes μ and σ^2 related to each alternative. Based on these normal PDFs, the values of the 5th, 25th, and 50th percentiles were obtained. For practical reasons, all figures were rounded to the nearest hundred. For example, in an alternative including the combination of the levels μ_{W1} and σ^2_{W1} (red alternative in the example of the choice card presented in Fig. 3, which happens to coincide with the scenario *W1* shown in Fig. 2), farmers were shown the following information: in 1 year out of 20, they would receive less than 200 m^3/ha/year; in 5 years out of 20, they would receive less than 1200 m^3/ha/year; and in 10 years out of 20, they would receive less than 2000 m^3/ha/year. Similarly, in the alternative derived from the combination of the levels μ_{SQ} and σ^2_{W1} (orange alternative in Fig. 3), the information shown to farmers indicated that they would receive less than 300 m^3/ha/year, 1600 m^3/ha/year, and 2600 m^3/ha/year, respectively, in 1 year, 5 years, and 10 years out of 20.

The same procedure was used for CE_WTA and CE_WTP, although the colors were changed: orange and red for CE_WTA and blue and green for CE_WTP. In both valuation exercises, color grey color was used for denoting the SQ or no change scenario.

As well as presenting an accurately framed CE, in which increases and decreases in water supply reliability were equally framed, several measures were taken to ameliorate potential biases related to the elicitation technique. First, in the implementation of the CE, the help of the irrigation district management board was enlisted; they informed the irrigators of the usefulness of the study, and the fact that the results would inform their future management decisions. This significantly increased survey consequentiality, thus substantially reducing hypothetical bias. Second, before presenting the sequence of choices, a 'cheap talk' was given, focusing on the importance of respondents declaring their actual preferences to properly support policy design. Third, the CEs were randomly ordered to control for potential sequence biases [35]. Therefore, any WTA-WTP disparity found in the study would not simply be an artifact resulting from an inaccurate elicitation technique or a poor valuation design.

4.2. Experimental design and data gathering

A two-stage sequential experimental design was geared toward minimizing the expected D_b-error [36]. This optimization is computed by simulation on the basis of some prior distributional assumptions. In the first stage, for the pre-test, efficient designs (D_b-error = 0.084 and 0.108, respectively, for CE_WTP and CE_WTA) with priors assumed to follow triangular distributions were used, allowing them to vary within a wide range of values. In a second stage, the estimates of multinomial logit models (MNL) calculated from the 40 interviews gathered during the pre-test were used to set priors –assumed to be normally distributed– in order to generate the D_b optimal efficient designs (D_b-error = 0.049 and 0.081, respectively, for CE_WTP and CE_WTA). These final efficient designs included 24 choice tasks distributed into four blocks for each CE exercise, with each farmer being presented with one block of six

Table 3
Descriptive statistics of survey respondent characteristics.

Variable (units)	Mean or rate
Age50: Farmer is 50 years old or over (1 = Yes, 0 = No)	0.68
Consumhi: Farmer perceives that the level of water consumption for the farm's main crop is above the average for the same crop within the IC (1 = Yes, 0 = No)	0.12
Fincomhi: Farm income represents at least 75% of total household income (1 = Yes, 0 = No)	0.61
Hoareahi: Horticultural area above the IC average (1 = Yes, 0 = No)	0.19
Iarea15: Total irrigated area within the IC above 15ha (1 = Yes, 0 = No)	0.51
Irrigic: Procedure to decide how much and when to irrigate: As suggested by the IC staff (1 = Yes, 0 = No)	0.19
Tarea: Total farm area above 30ha (1 = Yes, 0 = No)	0.24
Waterha: Average irrigation water needs (m^3/ha/year)	2948
Watprohi: Average water productivity (gross margin/total water consumed) above the IC average (1 = Yes, 0 = No)	0.37
Wtpfirst: CE order (1 = CE_WTP was presented first, 0 = CE_WTA was presented first)	0.51

Note: There were no missing values, so N = 196 for all variables. Standard deviation for *Waterha*: 1108.

choice tasks per CE exercise (i.e., 12 choice tasks in total, including six choice tasks for CE_WTP and six choice tasks for CE_WTA). In order to account for order effects in WTA-WTP disparity, the CE exercises were administered in random order, so that half of the irrigators interviewed started with the block for CE_WTP, and the other half with the block for CE_WTA.

A representative sample of irrigators operating in Santaella IC (n = 205, accounting for 13.1% of the total number of farmers in the district) was drawn following a quota sampling procedure accounting for farm size. An *ad hoc* questionnaire was designed to collect the information needed for the empirical analysis regarding the two CE exercises proposed and the farm and farmer characteristics. Questionnaires were completed through face-to-face interviews.

The representativeness of the sample was confirmed using chi-square tests, which did not reject the null hypothesis of equality of sample and population proportions in terms of age, gender, farm size, and crop distribution variables. Thus, it is reasonable to assume that the results obtained can be extrapolated to the whole population of irrigators in Santaella IC (N = 1563 farmers).

Of these irrigators' responses, five were considered to be protests, which were defined as respondents who always chose the status quo alternative and who gave protest reasons for doing so [37]. The main protest reasons stated were skepticism regarding the possibility of improving water supply, lack of trust in the implementing institution, and moral grounds for refusal, such as the belief that 'water should not be traded'. In addition, four responses were identified as providing low-quality information due to a misunderstanding of the choice sets (according to the interviewer's judgment), reducing the total number of valid questionnaires eventually obtained to 196. Apart from the aforementioned protest responses due to skepticism, no issues with regard to the perceived credibility of CE attributes and levels were communicated to the interviewer.[1]

4.3. Econometric specification

Latent-class specifications were used to analyze the choices between alternative levels of water supply reliability. Two main reasons justify the use of a latent-class modeling approach here, especially compared to other mixed logit solutions (e.g., random parameter models): first, it systematically showed a better goodness of fit; and second, it enables a deeper analysis of preference heterogeneity, which is an explicit objective of the study, by identifying groups of irrigators with similar preference patterns that would otherwise be unobserved by the analyst.

The final model was an adjusted latent class model (SALCM). The SALCM specification was proposed by Magidson and Vermunt [38], and is built on a standard latent class model (LCM) specification [39], where differences in the error variance across respondents are controlled. While in LCM, analysts hypothesize that there are several discrete latent classes of individuals according to their preferences, in SALCM, individuals are probabilistically assigned based on not only their preferences but also scale classes [40,41]. This reduces confounding effects between preference and scale heterogeneity, which can produce biased welfare estimates [40,42]. To the authors' knowledge, this is the first study using SALCM to analyze farmers' preferences, despite the ever larger number of CE applications relying on farmer surveys that can be found in the literature [37].

In our particular case, scale-adjusted modeling is especially recommended as WTP and WTA values may well be affected by high scale heterogeneity [14]. Moreover, the latent class approach is also suitable as we hypothesize that there must be different well-defined patterns of WTA-WTP disparities [43] according to the diverse values irrigators assign to gains and losses related to changes in water supply reliability. The identification of these patterns enables the identification of useful policy-relevant implications [39].

[1] Initially, we had some concerns about differences between the perceived credibility associated with improvements in irrigation water supply reliability and that associated with deteriorations, particularly because of the severe water scarcity that characterizes the river basin where the case study is located. However, the respondents were informed that the reallocations of irrigation water associated with the improvement and deterioration scenarios would be done by means of several water policy instruments, including improvements in water infrastructure and the implementation of water banks and water markets, among others. These explanations helped respondents to better understand how the different scenarios would be attained; probably as a result of these efforts, no differences were detected in the perceived credibility of the two CE scenarios.

Table 4
Modeling results.

	MNL		LCM without restrictions and interactions						LCM with restrictions and interactions with ASCs						SALCM with restrictions and interactions with ASCs, and scale heterogeneity with covariates					
			pClass1		pClass2		pClass3		pClass1		pClass2		pClass3		pClass1		pClass2		pClass3	
			Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Membership probability			0.43		0.49		0.08		0.29		0.29		0.42		0.33		0.22		0.45	
Preference heterogeneity																				
μ WTP (10^3 m^3/ha/year)	0.057	0.100	0.163	0.150	0.324	0.394	1.300	1.168	−0.166	0.302	0.340*	0.193	–		0.578*	0.320	0.446**	0.210	–	
μ WTA (10^3 m^3/ha/year)	0.820***	0.169	1.370***	0.288	0.992**	0.461	1.869***	0.517	3.235***	0.639	1.092***	0.293	–		0.371	1.214	4.184***	1.125	–	
σ^2 WTP (10^6 (m^3/ha/year)^2)	−0.209***	0.077	−0.166	0.111	−1.022***	0.323	−4.093***	1.284	−0.129	0.203	−0.155	0.128	–		−0.124	0.183	−0.291**	0.134	–	
σ^2 WTA (10^6 (m^3/ha/year)^2)	−0.252***	0.057	−0.406***	0.100	−0.499**	0.211	−0.453***	0.120	−0.855***	0.184	−0.327***	0.095	–		0.314	0.408	−1.070***	0.320	–	
EUR-WTP (€10/ha/year)	−0.193***	0.019	−0.188***	0.023	−2.252**	0.878	−1.149	0.749	−1.598***	0.257	−0.140***	0.025	–		−1.874***	0.318	−0.079***	0.025	–	
EUR-WTA (€10/ha/year)	0.073***	0.021	0.064*	0.035	0.157*	0.080	0.151***	0.040	0.291***	0.056	0.034	0.035	–		0.269*	0.143	0.285***	0.091	–	
ASC_{SQ}-WTP	0.360***	0.102	−1.740***	0.234	0.724*	0.423	3.336***	1.100	−0.977***	0.382	−1.930**	0.414	6.513***	0.972	−2.286***	0.476	−2.289**	0.930	58.481***	16.520
ASC_{SQ}-WTA	2.369***	0.153	1.992***	0.241	4.977***	0.664	−1.419***	0.445	−0.178	0.470	1.243***	0.293	3.103***	0.166	5.857***	1.976	2.431***	0.732	4.282***	0.387
ASC_{SQ}-WTP × *Wtpfirst*									−2.044***	0.383	−0.171	0.524	–		−0.636*	0.365	−0.567	1.467	–	
ASC_{SQ}-WTA × *Wtpfirst*									9.698	6.663	0.329	0.307	–		2.223	1.637	7.509***	2.757	–	
ASC_{SQ}-WTP × *Fincomhi*									−0.653*	0.341	−0.314	0.517	–		0.146	0.386	−15.343	10.741	–	
ASC_{SQ}-WTA × *Fincomhi*									2.143***	0.488	0.269	0.307	–		27.395***	8.959	−2.783***	1.079	–	
Class constant			0.498	0.132	0.624**	0.128	−1.122***	0.173	−0.127	0.117	−0.124	0.116	0.251**	0.098	0.012	0.137	−0.358**	0.153	0.346***	0.097
Scale heterogeneity																				
Membership prob. sClass1															0.80					
sClass1's log-scale factor															1					
Membership prob. sClass2															0.20					
															−2.460***	0.215				

(*continued on next page*)

Table 4 (*continued*)

	MNL	LCM without restrictions and interactions						LCM with restrictions and interactions with ASCs						SALCM with restrictions and interactions with ASCs, and scale heterogeneity with covariates					
		pClass1		pClass2		pClass3		pClass1		pClass2		pClass3		pClass1		pClass2		pClass3	
		Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
sClass2's log-scale factor																			
Watprohi														0.569***	0.167				
Hoareahi														−0.401**	0.176				
sclass constant (sClass2 vs. sClass1)														−1.409***	0.196				
Goodness-of-fit statistics																			
LL	−1581.4	−1106.9						−1103.0						−987.5					
BIC	3205.0	2351.0						2353.8						2143.9					
Pseudo-R^2	0.101	0.511						0.509						0.585					
Parameters	8	26						28						32					

***, **, * denote significance at 1%, 5%, and 10% level, respectively. All models include 7056 observations from 196 respondents.

The basic assumption of latent class approaches specifies c ($1, \ldots, C$) latent segments or classes of respondents within the population, each showing a marked profile in terms of preference structure. Each respondent is allocated to a single class based on a membership probability, which is unknown to the analyst. The utility (U) of alternative i to individual n (available within the set of j alternatives in a choice situation t) who belongs to class c, can be written as:

$$U_{int|c} = \beta_c X_{int} + \eta_{ic} + \varepsilon_{int} \tag{1}$$

where X is a vector of attributes, β_c is a class-specific parameter vector, η are alternative-specific constants (ASC), and ε is an iid type I extreme value distributed error term with variance $\pi^2/6\lambda$,[2] with λ representing a scale parameter. Within each class, choice probabilities are assumed to be generated by the multinomial logit model (MNLM). Unlike LCM, where λ is normalized to 1 and omitted, in SALCM the scale parameter is allowed to vary across different scale classes (s), thus assuming that individuals within the same preference class may display different levels of uncertainty. Let λs be the scale parameter specific to each scale class s, then the choice probability for alternative i conditional on preference class c is:

$$Pr_{n|c}(i) = \sum_{s=1}^{S} \pi_s \frac{\exp\left(\lambda_s \left(\beta_c X_{jnt} + \eta_{ic}\right)\right)}{\sum_{j=1}^{J} \exp\left(\lambda_s \left(\beta_c X_{jnt} + \eta_{jc}\right)\right)} \tag{2}$$

where π_s represents scale membership probabilities, and $\lambda_1 = 1$ for identification purposes. The overall probability of the sequence of choices ($y_1, y_2, \ldots, y_T$) is:

$$Pr([y_1, y_2, \ldots, y_T]) = \sum_{c=1}^{C} \pi_c \left[\prod_{t=1}^{T} \left(\sum_{s=1}^{S} \pi_s \frac{\exp\left(\lambda_s \left(\beta_c X_{jnt} + \eta_{ic}\right)\right)}{\sum_{j=1}^{J} \exp\left(\lambda_s \left(\beta_c X_{jnt} + \eta_{jc}\right)\right)} \right) \right] \tag{2}$$

In our specific application, additional sources of preference and scale heterogeneity were controlled in the SALCM. With regard to the former, interaction terms with the ASCs (η) were incorporated into the model following theoretical expectations related to order [44] and farm income [15] effects on general willingness to participate.[2] Moreover, individual-specific status quo information was considered ex-post, which proved to significantly improve model fit compared to assuming the same average status quo for all the respondents.[3] With regard to the latter, following the suggestion by Hess and Train [46] to further differentiate between preference and scale heterogeneity, covariates were used to delve deeper into scale heterogeneity. The following procedure was employed to select scale covariates: first, variables consistent with the theoretical framework were selected; second, those significant (at the 0.1 level) in single-covariate models were retained; and third, those found to be significant in models with multiple covariates were the ones ultimately retained. As suggested by Flynn et al. [47] and Glenk et al. [48], the second and third steps were carried out taking care to ensure that covariates did not create instability in the latent class solution or exhibit unintuitive patterns across covariate categories.

In addition, due to the high proportion of serial non-participants (for both CE_WTP and CE_WTA), one class was modeled including restrictions on attribute parameters to deal with full attribute non-attendance, in a similar fashion to Glenk et al. [48].

The number of latent preference classes or *pclasses*, imposed exogenously by the analyst, was determined based on the evaluation of model fit information criteria (BIC, AIC, and CAIC), which revealed a relatively low decrease beyond three-pclass solutions (especially in SALCMs), together with the analyst's appraisal of model parsimony and interpretation of policy implications [49]. Model fit information is shown in Appendix 1 for one-to seven-class solutions for specifications incorporating: a) preference heterogeneity; b) preference and scale heterogeneity (with two scale classes or *sclasses*); c) preference heterogeneity with interactions with the ASCs and restrictions; and d) preference heterogeneity with interactions with the ASCs, restrictions, and scale heterogeneity (two sclasses) including covariates. Two-sclass ($S = 2$) solutions were used in SALCM specifications as a higher number of sclasses did not substantially improve the selection criteria mentioned above.[4]

With regard to welfare estimates, the Krinsky-Robb bootstrapping method [50] was used to compute the median and confidence intervals of WTP, WTA, and ratio estimates. Both marginal and total WTP and WTA estimates were calculated, in the latter case following Hanemann [51] to estimate welfare changes in symmetric scenarios of improvements and deteriorations of water supply reliability. The scenarios considered were defined for changes of ±10%, ±25%, and ±50% in the irrigation water supply reliability.

To further explain class membership with respondents' characteristics and opinions without affecting class membership probabilities and parameter estimation, a step-3 approach was used. Such an approach consists of investigating the association between the posterior class membership from the latent class model with external variables (either predictors or outcomes). Here, a covariate step-3 model is employed, with covariates acting as predictors of class membership. In this model, the probability of being assigned to class a_i

[2] Other effects related to substitution, transaction costs, and attitudes toward uncertainty (especially related to climate change and future competing water uses) mentioned in Section 2 were also explored but proved not to be significant.

[3] This finding lends support to effects of reference-dependence, as evidenced by Rose and Masiero [45] using a pivoted design. However, a pivoted design could not be implemented here due to time and resource constraints. Models including the same status quo for all respondents are available on request.

[4] Full model results are available on request to authors.

given by z_i set of individual-specific covariates can be calculated as [52,53]:

$$P(a_i|z_i) = \sum_{c=1}^{C} P(c|z_i)P(a_i|c) \tag{3}$$

where c is the true class membership (obtained from the SALCM's posterior classification), $P(c|z_i)$ is the probability of being assigned to the true class c given individual-specific information z_i, and $P(a_i|c)$ is the conditional response probabilities between assigned and true membership. In particular, following Vermunt and Magidson [53], we use proportional class assignment and the maximum likelihood adjustment method to correct biases created by classification errors.

Step-3 and SALCM models were computed using LatentGOLD 5.1 [53]. For the latter model, it is worth noting that the specification incorporates a log-scale factor to ensure non-negative values.

Table 3 shows the descriptive of the variables related to respondents' characteristics used in the final models.

5. Results

5.1. Modeling preference and scale heterogeneity

Table 4 shows the results of the following models (all using pooled data from CE_WTP and CE_WTA): a) MNL; b) 3-pclass LCM; c) 3-pclass LCM model with variables interacting with the ASCs and restrictions; and d) 3-pclass SALCM with variables interacting with the ASCs, restrictions, and scale heterogeneity (with 2 sclasses) with covariates.

Results for the MNL show that all attributes (except μ WTP) and the ASCs are highly significant, and present the expected sign: positive for the μ parameters (meaning the higher the mean water supplied, the greater the utility); negative for the σ^2 parameters (meaning the higher the variance of the water supplied, the lower the utility); and negative or positive depending on whether the irrigator has to pay (EUR-WTP) for water supply improvements or accept (EUR-WTA) deteriorations in the supply. Positive ASCs (ASC_{SQ}-WTP and ASC_{SQ}-WTA) mean utility for the status quo alternative.

The three-class LCM is more informative, showing that there are three classes of irrigators grouped by their preferences toward the CE attributes. It is highly significant for all the attributes (except μ WTP) and there is a marked improvement in the goodness of fit with respect to MNL (for MNL pseudo-$R^2 = 0.11$, while for LCM pseudo-$R^2 = 0.51$). However, for both CE_WTP and CE_WTA, it fails to adequately group serial non-participants (i.e., those systematically choosing the status quo alternative in all choices), who account for 34% of the valid sample.[5]

For this reason, an LCM specification with a class with restricted parameters for all the attributes was subsequently used, also including interactions terms with the ASCs to delve deeper into preference heterogeneity. By doing so, serial non-participants were successfully grouped together in pClass3, as reflected by the ASCs parameters, which are positive, significant, and larger in magnitude. When comparing this and the previous LCM solution, it can be seen that they display a similar model fit, but the former outperforms the latter by successfully grouping together serial non-participants and showing significant order (*Wtpfirst*) and farm income (*Pfarminc*) effects on general willingness to participate. However, this last LCM solution does not make it possible to account for scale heterogeneity, which is the main reason why the SALCM specification was used in the form shown in Table 4.[6]

SALCM provides a significantly better fit than the previous models (pseudo-$R^2 = 0.58$) by considerably controlling for scale heterogeneity. Thissuggests relevant scale heterogeneity, though it seems that effects related to preference heterogeneity are comparatively greater, as shown by the relatively higher increase in model fit obtained from previous steps. Accordingly, the following description of results focuses on this SALCM solution.

The modeling results show three different classes of irrigators according to their preferences toward water supply reliability. Of the three, preference class 3 or pClass3 shows the highest membership probability (0.45), grouping together those who are unwilling to pay and/or accept, respectively, for positive and negative changes in the current water reliability. In particular, this is indicated by the large magnitude of the ASC_{SQ}-WTP and ASC_{SQ}-WTP parameters, meaning that irrigators allocated to this class show very high utility attached to the status quo alternative irrespective of the valuation context (WTP or WTA). Conversely, pClass2 comprises those who are willing to pay for and accept, respectively, positive and negative changes in both the mean and variance of irrigation water supplied. This class shows the lowest membership probability (0.22). Lying in between the two, pClass1 (membership probability = 0.33) includes those irrigators who are only willing to pay for improving water supply reliability (mainly by increasing the mean water supplied), and are generally unwilling to accept deteriorations in reliability. Additional insights about preference heterogeneity show significant order effects for pClass1 and pClass2 on the general willingness to pay and accept (as represented by the interactions ASC_{SQ}-WTP × *Wtpfirst* and ASC_{SQ}-WTA × *Wtpfirst*), respectively, coupled with the farm income effect on general willingness to accept in both classes (see ASC_{SQ}-WTA × *Fincomhi*).

[5] All serial non-participants are grouped in pClass2, though this class shows significant attribute parameters estimated from the non-serial non-participants also included in this class, thus providing a poor modeling solution.

[6] Following Davis et al. [54], we checked for potential sensitiveness to scale normalization, finding no significant effects on the results, on either membership probabilities or general preference patterns. In addition, specifications allowing for dependence between sclasses and pclasses were explored, but no significant relationship was found, so for parsimony the result assuming independence between them was retained. Models are available on request.

Table 5
Median marginal welfare estimates (in €/ha/year).

	pClass1				pClass2			
	Coeff.	Conf. Int. (95%)	Ratio WTA/WTP	Conf. Int. (95%)	Coeff.	Conf. Int. (95%)	Ratio WTA/WTP	Conf. Int. (95%)
WTP for increased μ ($+1000$ m^3/ha/year)	3.09*	(-0.46; 5.60)	n.a.		56.68**	(7.49; 101.67)	2.59**	(1.14; 10.56)
WTA for decreased μ (-1000 m^3/ha/year)	13.62	(-203.70; 208.04)			146.75***	(99.20; 252.37)		
WTP for decreased σ^2 (-10^6 (m^3/ha/year)^2)	0.67	(-1.44; 2.49)	n.a.		37.08**	(5.64; 79.50)	1.02**	(0.29; 4.57)
WTA for increased σ^2 ($+10^6$ (m^3/ha/year)^2)	−10.78	(-112.16; 47.94)			37.51***	(20.55; 72.19)		
WTP for any better water supply reliability (ASC_{SQ}-WTP)	13.95***	(9.98; 19.50)	58.29*	(-131.17; 373.28)	291.72**	(66.87; 852.48)	0.60**	(0.12; 3.43)
WTA for any worse water supply reliability (ASC_{SQ}-WTA)	797.71*	(-1896.50; 5193.89)			175.12***	(68.97; 454.14)		

***, **, * denote significance at 1%, 5%, and 10% level, respectively. No estimate can be calculated for pClass3.

Table 6
Median welfare estimates for different scenarios of water supply reliability (in €/ha/year).

	pClass1				pClass2			
	Coeff.	Conf. Int. (95%)	Ratio WTA/WTP	Conf. Int. (95%)	Coeff.	Conf. Int. (95%)	Ratio WTA/WTP	Conf. Int. (95%)
Scenario 1-WTP (+10% in μ and −10% in σ^2)	15.53***	(12.48; 19.88)	52.17**	(4.26; 354.06)	321.27***	(83.18; 927.33)	0.72***	(0.19; 3.52)
Scenario 1-WTA (−10% in μ and +10% in σ^2)	797.71*	(-1896.50; 5193.89)			230.02***	(119.15; 540.63)		
Scenario 2-WTP (+25% in μ and −25% in σ^2)	16.73***	(14.01; 20.34)	48.09*	(-103.23; 297.10)	347.93***	(110.57; 892.40)	0.80***	(0.26; 3.24)
Scenario 2-WTA (−25% in μ and +25% in σ^2)	797.71*	(-1896.50; 5193.89)			273.44***	(161.98; 614.07)		
Scenario 3-WTP (+50% in μ and −50% in σ^2)	18.70***x	(15.72; 21.92)	43.36*	(-64.16; 246.26)	373.35***	(132.99; 905.08)	1.09***	(0.39; 3.67)
Scenario 3-WTA (−50% in μ and +50% in σ^2)	797.71*	(-1896.50; 5193.89)			400.32***	(266.70; 804.32)		

***, **, * denote significance at 1%, 5%, and 10% level, respectively. No estimate can be calculated for pClass3.

Table 7
Step-3 model (effects referred to pClass 3).

Variable	pClass1		pClass2		Wald test	Differences between class coefficients		
	Coeff.	SE	Coeff.	SE		pC1 *vs.* pC2	pC1 *vs.* pC3	pC2 *vs.* pC3
Tarea30	0.6630	0.5114	−0.9144	0.5993	5.43*	**		
Iarea15	−1.0866	0.4727	0.3328	0.4815	7.29**	**	**	
Waterha	0.0002	0.0002	0.0005	0.0002	6.54**			**
Irrigic	1.2276	0.4961	1.2964	0.5705	7.54**		**	**
Consumhi	0.4555	0.5843	1.4941	0.5847	6.72**	*		**
Age50	−0.9011	0.3848	−0.6775	0.4568	5.90*		**	
Intercept	−0.1577	0.6453	−2.0691	0.7817	7.25**			
Goodness-of-fit								
LL	−188.31							
BIC	450.51							
No. of coeff.	14							

** and * denote significance at 5% and 10% levels, respectively. Asterisks in the last three columns denote differences between class coefficients using Wald tests (e.g., for *Tarea30* there is a statistically significant difference at 5%-level between pClass1 and pClass2 coefficients). The coefficient for pClass3 is set to zero.

With regard to scale heterogeneity, a log-scale factor significantly different from zero is found for the two scale classes included in the SALCM specification. This proves scale heterogeneity among irrigators' preferences toward water supply reliability, with membership probability being 0.80 and 0.20 for sClass1 and sClass2, respectively. Remarkably, the log-scale factor value estimated at −2.46 (i.e., yielding a scale factor of 0.085) for sClass2 suggests that, compared to sClass1, this class is characterized by higher error variance, pointing to a lower choice consistency and certainty among members belonging to this class. Observing the covariates incorporated in the scale model, it can be seen that scale is positively related to an above-average water productivity (*Watprohi* = 1) and negatively related to an above-average area devoted to horticultural crops (*Hoareahi* = 1), meaning lower and higher respondents' choice certainty, respectively. We interpret the first result as reflecting the greater importance of the good under valuation for the irrigators (i.e., the higher the expected profitability from increased water use, the higher the importance attached to such use and, thus, the higher the response certainty). It could be argued that the second result is related to the greater complexity of the valuation exercise perceived by the respondent [55], as irrigators with horticultural crops typically decide among a wider range of crops (entailing different water needs) and, more importantly, these crops are characterized by higher uncertainty regarding expected profitability (not only due to higher production risk but also market risk) [56]. Hence, in each choice task, irrigators with a higher proportion of horticultural crops had to adjust their crop-mix decisions to the scenarios of water supply reliability presented in the alternatives, which implies considering uncertainty in expected profitability for their full range of available crop-mix alternatives. To some extent, this reflects previous findings on the inverse relationship between respondents' perceived certainty regarding choices and error variance [48].

5.2. *Welfare estimates*

Using the SALCM results shown above, we can estimate welfare changes for variations in water supply reliability. Table 5 shows marginal WTP and WTA estimates for improvements and deteriorations in reliability for each preference class, except pClass3, for which no estimate can be calculated (due to non-attendance to all the attributes). pClass1 irrigators show a significant marginal WTP for increasing mean water supplied, with a modest median estimate of €3.1 per increase of 1000 m^3/ha/year in μ, while no significant welfare estimates are obtained for the other attributes (i.e., WTA for decreased μ, and WTP and WTA for decreased and increased variance $-\sigma^2-$ of irrigation water supply). However, they present significant WTP and WTA estimates, respectively, for any improvement or deterioration of water supply reliability, with the median general WTP for improvements being €13.9/ha/year and, more remarkably, the median general WTA for deteriorations being €797.7/ha/year. The latter figure indicates very low willingness to receive monetary compensation in exchange for worsened irrigation water supply reliability. This is logically reflected in an extreme WTA/WTP ratio (median around 58). pClass2 irrigators are the only ones who show significant marginal WTP and WTA estimates for the two attributes considered, with estimates of €56.7 and €146.7 for increases and decreases of 1000 m^3/ha/year in μ, respectively, and €37.1 and €37.5 for decreases and increases of 10^6 (m^3/ha/year)^2 in σ^2. In addition, pClass2 irrigators show a significant and fairly high WTP and WTA for general improvements and deteriorations of water supply reliability (median estimates of €291.7 and €175.1/ha/year, respectively). As a result, these irrigators show moderate WTA/WTP ratios for these marginal welfare estimates, with median values of 2.6 and 1.0 for the attributes μ and σ^2 and 0.6 for departing from the status quo alternative.

In terms of impacts on welfare estimates, order effects were significant for pClass1's general WTP for improvements and pClass2's general WTA for deteriorations of water supply reliability. Those who were presented first with CE_WTP (*Wtpfirst* = 1) show a significantly higher WTP (estimated at +€3.4/ha/year, p-value<0.1) for pClass1 and far higher WTA (+€264.5/ha/year, p-value<0.01) for pClass2, as compared to the corresponding figures for those who were presented first with CE_WTA (*Wtpfirst* = 0). Very significant effects of farm income, represented by the *Fincomhi* variable, on welfare estimates were also found. Those whose household income is heavily dependent on farm income have significantly higher (+€961.7/ha/year, p-value<0.1) and lower WTA (−€98.6/ha/year, p-value<0.05) in pClass1 and pClass2, respectively.

Table 6 shows total welfare estimates for scenarios of 10%, 25%, and 50% of improvements in μ and σ^2 (enhanced water supply reliability scenarios 1-WTP, 2-WTP, and 3-WTP) and deteriorations in μ and σ^2 (worsened water supply reliability scenarios 1-WTA, 2-WTA, and 3-WTA). pClass1 irrigators show significant median WTP values in the range of €15.5–18.7/ha/year for the three scenarios of improvement considered, while WTA estimates remain invariant due to the non-significance of attribute parameters. However, ratio estimates seem to be more sensitive to the fact that WTP estimates are more certain (significant at 0.01 level) compared to WTA ones, showing values within the 43–52 range for this pclass. pClass2 irrigators show more sensitivity to changes in the water supply reliability scenarios, with significant median WTP and WTA values ranging within the €321–373/ha/year and €230–400/ha/year intervals, respectively. Consequently, WTA/WTP ratios for this pclass fall within the 0.7–1.1 interval.

5.3. Socioeconomic characteristics associated with class membership

Table 7 shows the step-3 model where class membership is predicted with covariates, using pClass 3 as the reference. The model shows that class membership can be predicted by a number of variables, including farm characteristics and management (namely, farm size, water needs, irrigation management following the IC's suggestions, and perceived water use for the main crop), and irrigators' socioeconomic characteristics (namely, age). In particular, compared to pClass3, pClass1 irrigators are more likely to have smaller irrigated areas (their irrigated area is more likely to be below 15 ha, *Iarea15*), make more use of the IC's suggestions for irrigation management decisions (*Irrigic*), and be younger than 50 (*Age50*), with no significant differences found among pclasses for the other variables. pClass2 irrigators are also more likely to make use of the IC's suggestions (*Irrigic*), opt for crops with higher average water needs (*Waterha*), and perceive that they consume more water for the main crop than other farmers with the same crop (*Consumhi*), with no significant differences found for the other variables compared to pClass3. Compared to pClass1, pClass2 are more likely to have smaller farm sizes (less likely to present a total farm area of over 30 ha, *Tarea30*), larger irrigated areas (*Iarea15*), and higher water use perception (*Consumhi*).

6. Discussion

6.1. Heterogeneity in the WTA-WTP disparity

Our results add to previous evidence showing the disparity between WTA and WTP values, but this is the first study to report such findings with regard to a common-pool resource used as a business input; in this case, irrigation water and its supply reliability. However, the most relevant insight provided by the analysis performed here is the individual-specific heterogeneity in the WTA-WTP disparity. Most of the existing literature assesses the disparity between WTA and WTP values in average or median terms (i.e., WTA-WTP disparity measures at the market level), generally ignoring the heterogeneous interpersonal preferences [16]. For instance, in the case of water-related markets or services, this issue has been analyzed focusing on the reliability of household water services [21] or the equilibrium prices in spot water markets [22]. Only a few studies have analyzed interpersonal heterogeneity in WTA-WTP disparity, all of which focus on specific characteristics of interest such as individuals' psychological traits [57], marketplace experience [58], or the reference-dependence [14]. Our study adds to the existing knowledge by comprehensively analyzing individual-specific heterogeneity in the WTA-WTP disparity, considering various different potential sources of this heterogeneity.

In particular, the latent class approach allowed to distinguish three profiles or classes of farmers according to their preferences.

- pClass2 can be labeled as 'traders' since they are willing to pay and accept payment for changes in the mean and variance of irrigation water supplied. They thus come close to displaying *homo economicus* behavior (showing a very low WTA-WTP disparity, with WTA/WTP ratios close to one). Notably, the fact that this class shows the smallest membership probability is in keeping with previous studies focusing on preference heterogeneity (e.g. Ref. [59]), which also found the class behaving in accordance with standard economic assumptions to be the smallest one.
- pClass3 can be labeled as 'full non-traders' since they do not trade off their irrigation water supply reliability at all (no WTA-WTP disparity can be assessed, though the serial status quo choice in the two DCE administered actually suggests WTP tending to zero and WTA showing extremely high values). These preferences could be explained with reference to their attitudes and opinions against water trading (i.e., irrigation water and related services considered as public goods that should be kept out of the market). The fact that this class contains the oldest irrigators and shows the least qualified management (as shown by *Age50* and *Irrigic* variables) would lend support to this interpretation, mirroring previous findings by Alcón et al. [60] and Giannoccaro et al. [22].
- pClass1 is an intermediate class that can be labeled as 'partial non-traders'. These farmers make minimal trade-offs in water supply reliability, especially with regard to worsening scenarios. This leads to very high WTA/WTP ratios, far more extreme than in the vast majority of previous studies [16]. There is a variety of possible explanations for this, including loss aversion, income effects, and profit-seeking, as shown below.

In spite of the preference heterogeneity, the results (especially those shown in Table 6) hint at the non-linearity of the utility curve associated with water supply reliability, which is something that the three classes of irrigators identified have in common. However, the results suggest marked differences among classes in terms of the shape of said curve. While previous studies provide evidence of the non-linearity of the utility curve for WTP and WTA in water-related goods [e.g., 14], to our knowledge, the present study is the first to show this for irrigation water supply reliability.

Moreover, SALCM models have also shown that within each pclass there are other sources of WTA-WTP heterogeneity. According to our results, such heterogeneity in pClass2 and pClass1 could be partially explained by varying degrees of the income effect. Neoclassical economic theory points to the income effect as one potential explanation for the pervasiveness of higher WTA than WTP, suggesting that individuals' income constrains their demand for goods/services in terms of WTP, but not the amount for WTA required as compensation for relinquishing these goods/services [13]. However, this interpretation only applies to consumers considering how to spend their fixed income among the wide array of goods and services meeting their needs. This is not the case for irrigators valuing improvements and deteriorations in their water supply reliability, taking into account the fact that irrigation water is an input for their business. In these situations, it makes more sense to account for effects related to business income (i.e., farm income) or the dependence of household income on this business, as any change in the availability of inputs (irrigation water availability in our case study) could entail relevant changes in business income (gains or losses). Thus, when changes in input availability are considered, any effect related to income must be carefully analyzed, with the final impact depending on how these changes affect both business revenues and costs. In our case, pClass1 irrigators who are more reliant on farm income have a significantly higher WTA, suggesting that any worsening in water supply reliability involves relevant income losses (maybe because they have already adjusted their water use to lower water consumption levels, as shown in the step-3 model for variables *Waterha*[7] and especially *Consumhi*). Meanwhile, pClass2 irrigators whose income heavily relies on farm income show lower WTA, suggesting that their farm income is less sensitive to deteriorating water supply (maybe due to irrigators of this class still making excessive use of irrigation water, as shown by *Waterha* and *Consumhi* variables[8]). For pClass1, the farm income effect explains a larger WTA/WTP ratio, similar to the effect found for consumers; conversely, for pClass2, the farm income effect entails a smaller WTA/WTP ratio.

Our results indicate significant heterogeneity in preferences for irrigation water reliability, showing general asymmetric preferences for improvements and deteriorations in most water reliability attributes, as the losses associated with a decline in water reliability are higher than corresponding gains. This is consistent with the concept of loss aversion in the prospect theory [14]. In this sense, it is worth noting that interindividual differences in loss aversion, causing differential endowment effects [25], can be suggested as another relevant source of heterogeneity in WTA-WTP disparity. This is in line with the evidence found in several experimental studies accounting for heterogeneous loss aversion among farmers [e.g., 26,27].

6.2. Methodological aspects

Looking at the results from a methodological perspective, the first finding indicates that WTP and WTA for the same good may be notably affected by scale heterogeneity. The fact that model fit significantly improves when accounting for it suggests that it may be advisable to consider scale heterogeneity in analyses focusing on the WTA-WTP disparity related to water use. In particular, when the water in question represents a productive input, we find that scale heterogeneity is very much guided by the role played in the business profitability (i.e., average irrigation water productivity), and the uncertainty about business performance (i.e., uncertainty regarding final water productivity in a single season). Though this study attempted a more in-depth exploration of factors determining scale heterogeneity, it is worth acknowledging that the scale analysis performed is probably limited by the moderate sample size and the large number of model parameters involved. Thus, it can be argued that there might be other sources of this heterogeneity that remain undetected in this study due to such limitations. An analysis controlling for a higher number of scale determinants would likely yield more accurate results (as suggested by Hess and Train [46]), but this should be left for further investigation with larger sample sizes.

The other main methodological finding concerns the significant order effects uncovered in the valuation exercise. Interestingly, the results indicate that the ordering of experiments (CE_WTP and CE_WTA) significantly affects the final results, with these effects varying from one respondent to another. Several studies focusing on WTA-WTP disparity have controlled for order effects, though very few report significant effects (e.g. Ref. [44]). There could be a number of reasons for order effects, including reference-dependence [14], profit-seeking behavior [13], preference learning effects [61], strategic behavior in hypothetical settings [44], and more generally, misconception about the experiments [62]. None of these reasons can be fully ruled out as the underlying explanation for the order effects found here, though we can plausibly speculate that profit-seeking behavior and reference-dependence effects may prevail (especially given the means used to ameliorate hypothetical biases). With regard to the former, it can be argued that the nature of the good under valuation (i.e., irrigation water, a common-pool resource used as a business input) incentivizes profit-seeking behavior in the two pclasses willing to trade off. Those who strongly value losses and undervalue gains (i.e., pClass1-Partial non-traders) lean toward even lower WTP values, while those similarly valuing gains and losses (i.e., pClass2-Full traders) lean toward increasing WTA. In any case, we cannot be sure that this is not confounded with reference-dependence effects in the sense that the differences in how the change in input (irrigation water) use impacts the farmers' utility function in each pclass (changes in supply reliability affect business revenues and costs) could also play a relevant role. All this makes it clear that the role of order effects in WTA-WTP disparity deserves further research, especially using non-hypothetical settings.

[7] Mean water needs (*Waterha*) per pclass are as follows (in m^3/ha/year): 3225, 3021, and 2763 for pClass2, pClass1, and pClass3, respectively.

[8] It could be argued that this excessive water use is also behind the different WTA/WTP ratios found for pClass2 for scenarios of moderate changes (i.e., ratios of 0.7 and 0.8 for Scenarios 1 and 2, as shown in Table 6) compared to that for significant changes (ratio of 1.1 for Scenario 3). As these irrigators use more water, it can be assumed that they are generally more inclined to pay for improvements to water supply reliability than to accept compensation for its deterioration. This general inclination towards paying for improvements rather than accepting compensation for deteriorations captured by the ASC term outweighs the higher marginal WTP estimates (compared to WTA estimates −as shown in Table 5) in the levels of the attributes μ and, to a much lesser extent, σ^2 for moderate changes but not for significant changes. For the latter scenarios, the deterioration in the mean water supply is so great it makes the pClass2 irrigators' total WTA higher than the total WTP for the equivalent improvement.

Finally, the reference point used in the valuation exercises (for both WTP and WTA) merits specific discussion. Koetse and Brouwer [14] show how WTP and WTA estimates (and the gap between them) differ depending on the reference point defined in the experiment. In our case study, the same reference point (probability function derived from historical water allotments in the past 20 years) is used for both CEs because the irrigators are clearly aware of it (they have to manage their farms with these water allotments every year). However, it is likely that this reference point is already shifting due to climate change (i.e., current expectations for irrigation water allotments are probably not those described in the distribution function fitted with historical data) and will continue to do so in the future. This could raise some concerns about the suitability of the reference point considered and, thus, about the results obtained.

The use of the historical reference point, instead of considering a reference point that accounts for climate change, is justified for three main reasons: a) the difficulty of setting a sound future distribution of water allotments accounting for the feasible impact of climate change (a task which goes well beyond the scope of this paper); b) the fact that the climate change reference point would be an unknown scenario for irrigators, subject to a high level of uncertainty, which could potentially cause biased assessments; and c) the resources constraints for this research (i.e., the sample size needed to carry out a split sample approach).

In any case, the results shown here are helpful for anticipating gains and losses related to higher and lower levels of water supply reliability in the future. However, bearing in mind the findings reported by Koetse and Brouwer [14], such gains and losses could be expected to differ in scenarios accounting for the current and future impacts of climate change (i.e., reference points where the mean water supply decreases and its variance increases). In particular, one of the implications drawn from their results is that we would expect WTA estimates to show a greater change than WTP estimates. Certainly, further research would be needed to confirm these expectations.

7. Concluding remarks

The present paper contributes to the existing knowledge in several ways, including the estimation of the WTA-WTP disparity for a common-pool resource such as irrigation water, the investigation of preference and scale heterogeneity in such a valuation context, and the identification of (farm) business income and order effects as significant determinants of the disparity. To do so, the analysis relies on a discrete choice experiment approach with attributes based on probability density functions (representing changes in irrigation water supply reliability in terms of improvements and/or deteriorations in the mean and variance of the supply) and a scale-adjusted latent class modeling approach used for the first time with farmers.

The results show marked heterogeneity in the WTA-WTP disparity, with the identification of the following three classes of irrigators according to their preferences (in decreasing order of membership probability): full non-traders (0.45), partial non-traders (0.33), and traders (0.22). The first two classes show very high loss aversion, most probably due to issues of property rights (as, in the case study considered, irrigation water represents a business input with centralized allocation by a public agency), with full non-traders entirely unwilling to trade off their irrigation water supply reliability and partial non-traders only slightly willing to do so. Further insights about preference heterogeneity relate to the finding that significant farm income and order effects vary across classes. The former basically reflects changes in business revenue and costs as a result of changes in input availability and, as such, shows diverse impacts depending on the type of farm. The latter (relative to which choice experiment was administered first, CE_WTP or CE_WTA) may be attributed to a variety of underlying reasons, among which reference-dependence effects and profit-seeking behavior are probably the most plausible –though this undoubtedly represents an open question for future research.

In addition, the modeling approach allowed us to separate preference from scale heterogeneity, showing significant scale heterogeneity. Particularly, out of the two scale classes identified, the smallest one (membership probability = 0.20) comprises respondents with higher choice uncertainty, with this uncertainty being decreased and increased by business profitability and insecurity about such profitability, respectively. The identification of significant scale heterogeneity suggests that modeling approaches that consider both preference and scale heterogeneity may be advisable in future assessments of this type. In any case, the results call for further research to show the extent to which scale heterogeneity significantly affects WTP and WTA estimates in CEs focused on farmers and/or water use.

The results point to several policy-relevant implications. First, and probably most obviously, they provide evidence of the non-neutrality of the initial establishment of the property rights. Therefore, it could be argued that more flexible structures of water rights (e.g., the conversion into non-permanent rights) would yield more efficient results in water management at a basin scale. Second, they confirm the need to implement climate change adaptation measures, taking into account the high cost of any deterioration in water supply reliability measured in WTA terms (much higher than the WTP-based estimates suggest). Third, the success of demand-side instruments based on water trading (including water markets and banks) may be jeopardized by a failure to design policy accounting for the large and heterogeneous WTA-WTP disparity, farm income effects, and the differing disparity depending on the type and level of change promoted. This is of the utmost importance in semi-arid regions, where demand-side instruments often represent one of the very few available options to cope with cyclical water supply scarcity (i.e., drought management). However, in a context like the case study considered, where water markets and banks are strongly contested [63], policy-makers should innovate by combining them with incentives to promote participation, e.g., drought insurance, priority rights, or precautionary savings. This clearly represents an open avenue for further research.

Role of the funding source

Financial support for the conduct of the research and/or preparation of the article was provided by the Spanish Ministry of Science, Innovation and Universities, and the European Regional Development Fund (ERDF) through the research project IRRIDROUGHT [grant RTI2018-095407-B-I00]. These funding institutions had no involvement in study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

CRediT author statement

Anastasio J. Villanueva: Conceptualization; Methodology; Formal Analysis; Writing—Original Draft; Writing—Review and Editing; Visualization, José A. Gómez-Limón: Conceptualization; Methodology; Writing—Original Draft; Writing—Review and Editing; Visualization; Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix 1

Table A1
Goodness of fit values for the models estimated.

Classes	LL	BIC	AIC	CAIC	Parameters	Classif. error	R^2
(a) Preference heterogeneity							
1	−1581.4	3205.0	3178.7	3213.0	8	0.000	0.10
2	−1238.0	2565.6	2509.9	2582.6	17	0.015	0.42
3	−1106.9	2351.0	2265.7	2377.0	26	0.019	0.51
4	−981.4	2147.5	2032.8	2182.5	35	0.019	0.58
5	−923.9	2080.0	1935.8	2124.0	44	0.018	0.64
6	−896.6	2073.0	1899.2	2126.0	53	0.034	0.67
7	−876.8	2080.9	1877.7	2142.9	62	0.041	0.70
(b) Preference and scale heterogeneity (2 sclasses)							
1	−1350.3	2753.3	2720.5	2763.3	10	0.010	0.30
2	−1125.7	2351.7	2289.4	2370.7	19	0.032	0.50
3	−993.8	2135.5	2043.7	2163.5	28	0.018	0.58
4	−954.6	2104.4	1983.1	2141.4	37	0.092	0.62
5	−901.8	2046.4	1895.6	2092.4	46	0.019	0.66
6	−877.1	2044.4	1864.1	2099.4	55	0.164	0.71
7	−863.3	2064.5	1854.7	2128.5	64	0.168	0.72
(c) Preference heterogeneity with interactions with the ASCs and restrictions							
1	−1565.2	3193.7	3154.3	3205.7	12	0.000	0.11
2	−1253.1	2585.4	2536.2	2600.4	15	0.005	0.41
3	−1103.0	2353.8	2262.0	2381.8	28	0.022	0.51
4	−985.7	2187.8	2053.4	2228.8	41	0.019	0.58
5	−930.7	2146.4	1969.4	2200.4	54	0.027	0.63
6	−882.6	2118.8	1899.2	2185.8	67	0.071	0.67
7	−853.9	2130.1	1867.9	2210.1	80	0.043	0.70
(d) Preference heterogeneity with interactions with the ASCs, restrictions, and scale heterogeneity (2 sclasses) including covariates							
1	−1343.4	2771.3	2718.9	2787.3	16	0.011	0.30
2	−1107.6	2315.4	2253.1	2334.4	19	0.014	0.51
3	−987.5	2143.9	2039.0	2175.9	32	0.019	0.58
4	−957.6	2152.6	2005.1	2197.6	45	0.085	0.61
5	−895.3	2096.7	1906.5	2154.7	58	0.026	0.67
6	−858.6	2092.0	1859.2	2163.0	71	0.174	0.72
7	−839.7	2117.4	1845.4	2200.4	83	0.500	0.70

Note: LL, Log likelihood; BIC, Bayesian Information Criterion; AIC, Akaike's Information Criterion; CAIC, Consistent AIC; pclasses, preference classes; sclasses, scale classes.

References

[1] IPCC (Intergovernmental Panel on Climate Change), Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems, IPCC, Geneva, Switzerland, 2019.

[2] EEA (European Environment Agency), Climate Change Adaptation in the Agriculture Sector in Europe, European Environment Agency, Copenhagen, 2019, https://doi.org/10.2800/537176.
[3] J. Elliott, D. Deryng, C. Mueller, K. Frieler, M. Konzmann, D. Gerten, M. Glotter, M. Florke, Y. Wada, N. Best, et al., Constraints and potentials of future irrigation water availability on agricultural production under climate change, P. Natl. Acad. Sci. USA 111 (2014) 3239–3244, https://doi.org/10.1073/pnas.1222474110.
[4] P.H. Gleick, The changing water paradigm. A look at twenty-first century water resources development, Water Int. 25 (2000) 127–138, https://doi.org/10.1080/02508060008686804.
[5] F. Molle, P. Wester, P. Hirsch, River basin closure: processes, implications and responses, Agric. Water Manag. 97 (2010) 569–577, https://doi.org/10.1016/j.agwat.2009.01.004.
[6] C.M. Gómez, C.D. Pérez-Blanco, D. Adamson, A. Loch, Managing water scarcity at a river basin scale with economic instruments, Water Econ, Policy 4 (2018), 1750004, https://doi.org/10.1142/s2382624x17500047.
[7] D. Rigby, F. Alcón, M. Burton, Supply uncertainty and the economic value of irrigation water, Eur. Rev. Agric. Econ. 37 (2010) 97–117, https://doi.org/10.1093/erae/jbq001.
[8] M.A. Mesa-Jurado, J. Martin-Ortega, E. Ruto, J. Berbel, The economic value of guaranteed water supply for irrigation under scarcity conditions, Agric. Water Manag. 113 (2012) 10–18, https://doi.org/10.1016/j.agwat.2012.06.009.
[9] A.R. Bell, M.A.A. Shah, P.S. Ward, Reimagining cost recovery in Pakistan's irrigation system through willingness-to-pay estimates for irrigation water from a discrete choice experiment, Water Resour. Res. 50 (2014) 6679–6695, https://doi.org/10.1002/2014wr015704.
[10] F. Alcón, S. Tapsuwan, R. Brouwer, M.D. de Miguel, Adoption of irrigation water policies to guarantee water supply: a choice experiment, Environ. Sci. Pol. 44 (2014) 226–236, https://doi.org/10.1016/j.envsci.2014.08.012.
[11] M.D. Guerrero-Baena, A.J. Villanueva, J.A. Gómez-Limón, K. Glenk, Willingness to pay for improved irrigation water supply reliability: an approach based on probability density functions, Agric. Water Manag. 217 (2019) 11–22, https://doi.org/10.1016/j.agwat.2019.02.027.
[12] K. Arrow, R. Solow, P.R. Portney, E.E. Leamer, R. Radner, H. Schuman, Report of the NOAA panel on contingent valuation, Fed. Regist. 58 (1993) 4601–4614.
[13] Y. Kim, C.L. Kling, J. Zhao, Understanding behavioral explanations of the WTP-WTA divergence through a neoclassical lens: implications for environmental policy, Annu. Rev. Resour. Econ. 7 (2015) 169–187, https://doi.org/10.1146/annurev-resource-100913-012501.
[14] M.J. Koetse, R. Brouwer, Reference dependence effects on WTA and WTP value functions and their disparity, Environ. Resour. Econ. 65 (2016) 723–745, https://doi.org/10.1007/s10640-015-9920-2.
[15] J.K. Horowitz, K.E. McConnell, Willingness to accept, willingness to pay and the income effect, J. Econ. Behav. Organ. 51 (2003) 537–545, https://doi.org/10.1016/S0167-2681(02)00216-0.
[16] T. Tunçel, J.K. Hammitt, A new meta-analysis on the WTP/WTA disparity, J. Environ. Econ. Manag. 68 (2014) 175–187, https://doi.org/10.1016/j.jeem.2014.06.001.
[17] J.A. Gómez-Limón, Hydrological drought insurance for irrigated agriculture in southern Spain, Agric. Water Manag. 240 (2020), 106271, https://doi.org/10.1016/j.agwat.2020.106271.
[18] J.K. Horowitz, K.E. McConnell, A review of WTA/WTP studies, J. Environ. Econ. Manag. 44 (2002) 426–447, https://doi.org/10.1006/jeem.2001.1215.
[19] S. Del Saz-Salazar, F. Hernández-Sancho, R. Sala-Garrido, The social benefits of restoring water quality in the context of the Water Framework Directive: a comparison of willingness to pay and willingness to accept, Sci. Total Environ. 407 (2009) 4574–4583, https://doi.org/10.1016/j.scitotenv.2009.05.010.
[20] B. Lanz, A. Provins, I.J. Bateman, R. Scarpa, K. Willis, E. Ozdemiroglu, Investigating willingness to pay-willingness to accept asymmetry in choice experiments, in: S. Hess, A. Daly (Eds.), Choice Modelling: the State-Of-The-Art and the State-Of-Practice, Edward Elgar Publishing, Cheltenham, UK, 2010, pp. 517–541, https://doi.org/10.1108/9781849507738-024.
[21] D.H. MacDonald, M.D. Morrison, M.B. Barnes, Willingness to pay and willingness to accept compensation for changes in urban water customer service standards, Water Resour. Manag. 24 (2010) 3145–3158, https://doi.org/10.1007/s11269-010-9599-7.
[22] G. Giannoccaro, M. Castillo, J. Berbel, An assessment of farmers' willingness to participate in water trading in southern Spain, Water Pol. 17 (2015) 520–537, https://doi.org/10.2166/wp.2014.092.
[23] J.L. Knetsch, The endowment effect and evidence of nonreversible indifference curves, Am. Econ. Rev. 79 (1989) 1277–1284.
[24] R. Thaler, Toward a positive theory of consumer choice, J. Econ. Behav. Organ. 1 (1980) 39–60, https://doi.org/10.1016/0167-2681(80)90051-7.
[25] D. Kahneman, J.L. Knetsch, R.H. Thaler, Experimental tests of the endowment effect and the Coase Theorem, J. Polit. Econ. 98 (1990) 1325–1348, https://doi.org/10.1086/261737.
[26] T. Sproul, C.P. Michaud, Heterogeneity in loss aversion: evidence from field elicitations, Agric. Finance Rev. 77 (2017) 196–216, https://doi.org/10.1108/afr-05-2016-0045.
[27] A.H. Villacis, J.R. Alwang, V. Barrera, Linking risk preferences and risk perceptions of climate change: a prospect theory approach, Agric. Econ. 52 (2021) 863–877, https://doi.org/10.1111/agec.12659.
[28] C.R. Plott, K. Zeiler, Exchange asymmetries incorrectly interpreted as evidence of endowment effect theory and prospect theory? Am. Econ. Rev. 97 (2007) 1449–1466, https://doi.org/10.1257/aer.97.4.1449.
[29] J.M. Penn, W. Hu, The extent of hypothetical bias in willingness to accept, Am. J. Agric. Econ. 103 (2021) 126–141, https://doi.org/10.1111/ajae.12121.
[30] P. Liu, X. Tian, Downward hypothetical bias in the willingness to accept measure for private goods: evidence from a field experiment, Am. J. Agric. Econ. 103 (2021) 1679–1699, https://doi.org/10.1111/ajae.12205.
[31] P. Mariel, D. Hoyos, J. Meyerhoff, M. Czajkowski, T. Dekker, K. Glenk, J.B. Jacobsen, U. Liebe, S. Olsen, J. Sagebiel, et al., Environmental Valuation with Discrete Choice Experiments, Springer, Cham, Switzerland, 2021, https://doi.org/10.1007/978-3-030-62669-3.
[32] R.J. Johnston, K.J. Boyle, W.L. Adamowicz, J. Bennett, R. Brouwer, T.A. Cameron, N. Hanley, R. Scarpa, R. Tourangeau, C.A. Vossler, Contemporary guidance for stated preference studies, J. Assoc. Environ. Resour. Econ. 4 (2017) 319–405, https://doi.org/10.1086/691697.
[33] J.A. Gómez-Limón, M. Arriaza, A.J. Villanueva, Typifying irrigated areas to support policy design and implementation: the case of the Guadalquivir River Basin, Irrigat. Drain. 62 (2013) 322–329, https://doi.org/10.1002/ird.1747.
[34] D. Hensher, A. Hanley, J.M. Rose, W.H. Greene, Applied Choice Analysis: A Primer, Cambridge University Press, Cambridge, UK, 2005, https://doi.org/10.1017/CBO9781316136232.
[35] B. Day, I.J. Bateman, R.T. Carson, D. Dupont, J.J. Louviere, S. Morimoto, R. Scarpa, P. Wang, Ordering effects and choice set awareness in repeat-response stated preference studies, J. Environ. Econ. Manag. 63 (2012) 73–91, https://doi.org/10.1016/j.jeem.2011.09.001.
[36] R. Scarpa, J.M. Rose, Design efficiency for non-market valuation with choice modelling: how to measure it, what to report and why, Aust. J. Agric. Resour. Econ. 52 (2008) 253–282, https://doi.org/10.1111/j.1467-8489.2007.00436.x.
[37] A.J. Villanueva, K. Glenk, M. Rodríguez-Entrena, Protest responses and willingness to accept: ecosystem services providers' preferences towards incentive-based schemes, J. Agric. Econ. 68 (2017) 801–821, https://doi.org/10.1111/1477-9552.12211.
[38] J. Magidson, J.K. Vermunt, Removing the scale factor confound in multinomial logit choice models to obtain better estimates of preference, in: Sawtooth Software Conference, 2007, pp. 17–19. Santa Rosa (CA), October.
[39] S. Hess, M. Ben-Akiva, D. Gopinath, J. Walker, Advantages of Latent Class over Continuous Mixture of Logit Models, Institute for Transport Studies, University of Leeds, Leeds, UK, 2011.
[40] M. Thiene, J. Meyerhoff, M. De Salvo, Scale and taste heterogeneity for forest biodiversity: models of serial nonparticipation and their effects, J. For. Econ. 18 (2012) 355–369, https://doi.org/10.1016/j.jfe.2012.06.005.
[41] D. Rigby, M. Burton, J.L. Lusk, Journals, preferences, and publishing in agricultural and environmental economics, Am. J. Agric. Econ. 97 (2015) 490–509, https://doi.org/10.1093/ajae/aau102.
[42] P.F. Burke, C. Burton, T. Huybers, T. Islam, J.J. Louviere, C. Wise, The scale-adjusted latent class model: application to museum visitation, Tourism Anal. 15 (2010) 147–165, https://doi.org/10.3727/108354210X12724863327605.

[43] M.J. Koetse, Effects of payment vehicle non-attendance in choice experiments on value estimates and the WTA-WTP disparity, J. Environ. Econ. Policy 6 (2017) 225–245, https://doi.org/10.1080/21606544.2016.1268979.
[44] W. Moon, S.K. Balasubramanian, A. Rimal, Willingness to pay (WTP) a premium for non-GM foods versus willingness to accept (WTA) a discount for GM foods, J. Agric. Resour. Econ. 32 (2007) 363–382.
[45] J.M. Rose, L. Masiero, A comparison of the impacts of aspects of Prospect Theory on WTP/WTA estimated in preference and WTP/WTA space, Eur. J. Transport Infrastruct. Res. 10 (2010) 330–346.
[46] S. Hess, K. Train, Correlation and scale in mixed logit models, J. Choice Model. 23 (2017) 1–8, https://doi.org/10.1016/j.jocm.2017.03.001.
[47] T.N. Flynn, J.J. Louviere, T.J. Peters, J. Coast, Using discrete choice experiments to understand preferences for quality of life. Variance-scale heterogeneity matters, Soc. Sci. Med. 70 (2010) 1957–1965, https://doi.org/10.1016/j.socscimed.2010.03.008.
[48] K. Glenk, C. Hall, U. Liebe, J. Meyerhoff, Preferences of Scotch malt whisky consumers for changes in pesticide use and origin of barley, Food Pol. 37 (2012) 719–731, https://doi.org/10.1016/j.foodpol.2012.08.003.
[49] R. Scarpa, M. Thiene, Organic food choices and Protection Motivation Theory: addressing the psychological sources of heterogeneity, Food Qual. Prefer. 22 (2011) 532–541, https://doi.org/10.1016/j.foodqual.2011.03.001.
[50] I. Krinsky, A.L. Robb, On approximating the statistical properties of elasticities, Rev. Econ. Stat. 68 (1986) 715–719, https://doi.org/10.2307/1924536.
[51] W.M. Hanemann, Welfare evaluations in contingent valuation experiments with discrete responses, Am. J. Agric. Econ. 66 (1984) 332–341, https://doi.org/10.2307/1240800.
[52] A. Bolck, M. Croon, J. Hagenaars, Estimating latent structure models with categorical variables: one-step versus three-step estimators, Polit. Anal. 12 (2004) 3–27, https://doi.org/10.1093/pan/mph001.
[53] J.K. Vermunt, J. Magidson, Technical Guide for Latent GOLD 5.1: Basic, Advanced, and Syntax, Statistical Innovations Inc., Belmont (US), 2016.
[54] K.J. Davis, M. Burton, M.E. Kragt, Scale heterogeneity and its implications for discrete choice analysis, Land Econ. 95 (2019) 353–368, https://doi.org/10.3368/le.95.3.353.
[55] J. Swait, W.L. Adamowicz, Choice environment, market complexity, and consumer behavior: a theoretical and empirical approach for incorporating decision complexity into models of consumer choice, Organ. Behav. Hum. Dec. 86 (2001) 141–167, https://doi.org/10.1006/obhd.2000.2941.
[56] S.M. Sánchez-Cañizares, M. Dolores Guerrero-Baena, J.A. Gómez-Limón, Factors influencing the simultaneous adoption of risk management instruments in Mediterranean irrigated agriculture, J. Environ. Plann. Manag. (2021) 1–22, https://doi.org/10.1080/09640568.2021.1922364.
[57] N. Georgantzís, D. Navarro-Martínez, Understanding the WTA–WTP gap: attitudes, feelings, uncertainty and personality, J. Econ. Psychol. 31 (2010) 895–907, https://doi.org/10.1016/j.joep.2010.07.004.
[58] J.A. List, Does market experience eliminate market anomalies? Q. J. Econ. 118 (2003) 41–71, https://doi.org/10.1162/00335530360535144.
[59] B.J. McNair, D.A. Hensher, J. Bennett, Modelling heterogeneity in response behaviour towards a sequence of discrete choice questions: a probabilistic decision process model, Environ. Resour. Econ. 51 (2012) 599–616, https://doi.org/10.1007/s10640-011-9514-6.
[60] F. Alcón, S. Tapsuwan, R. Brouwer, M. Yunes, O. Mounzer, M.D. de-Miguel, Modelling farmer choices for water security measures in the Litani river basin in Lebanon, Sci. Total Environ. 647 (2019) 37–46, https://doi.org/10.1016/j.scitotenv.2018.07.410.
[61] J. Zhao, C.L. Kling, Welfare measures when agents can learn: a unifying theory, Econ. J. 119 (2009) 1560–1585, https://doi.org/10.1111/j.1468-0297.2009.02272.x.
[62] C.R. Plott, K. Zeiler, The willingness to pay-willingness to accept gap, the "endowment effect", subject misconceptions, and experimental procedures for eliciting valuations, Am. Econ. Rev. 95 (2005) 530–545, https://doi.org/10.1257/0002828054201387.
[63] A.J. Villanueva, K. Glenk, Irrigators' preferences for policy instruments to improve water supply reliability, J. Environ. Manag. 280 (2021), 111844, https://doi.org/10.1016/j.jenvman.2020.111844.