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Valuing improvements in urban water security: evidence of heterogeneity derived from a latent class model for eastern Australia

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Abstract

In many Australian cities the response to drought has included the imposition of mandatory constraints over how water is used by households, often termed 'water restrictions'. A similar rationing approach has been witnessed in California's recent drought. The aim of water restrictions is to slow the depletion of water storage but restrictions have also been criticised for the costs they impose on specific water users. In order to gain insight into the potential magnitude of the cost of water restrictions, this study uses a choice experiment to investigate the non-market values for specific attributes associated with the outcomes of drought restrictions. This information was sought to understand the community's willingness to pay for attributes relating to the extent, frequency and duration of water restrictions. The paper reports a latent class choice model for a major city in eastern Australia and investigates heterogeneity in preferences towards increasing water availability during drought. This study departs from the existing literature by conducting the choice experiment in a context where water supply is relatively abundant. This unique framing of the choice experiment allows for a useful comparison with existing studies and also raises challenges about the interpretation of the data for planning purposes.

Key words: urban water; choice experiments; consumer behaviour; latent class model

1. Introduction

In most Australian cities the response to drought has included the imposition of mandatory constraints on how water is used by households, often termed 'water restrictions'. The aim of water restrictions is to slow the depletion of water storage during drought to extend the time for rains to occur and/or provide lead time for supply augmentation but the relative costs of this approach have been questioned on several fronts (see for example, Productivity Commission 2011). In particular, water restrictions have been criticised for the costs they impose on specific water users and the apparent imprecision with which such costs are then included in water planning decisions (see, for e.g., Edwards 2008; Cooper, Burton and Crase 2011).

One of the major challenges for water planners is the extent of uncertainty that attends water availability in the future especially when supplies are reliant on rainfall. This proved particularly vexing in Australia during the first decade of this century. The experience in some eastern states in the 2000s, where drought was more persistent than usual, also shows that there are often considerable political pressures when drought coincides with uncertainty and discussion about climate change (see, Ben-David 2013). The so-called 'millennium drought' and the prospect of climate change justifiably remains strong in the minds of Australia's water planners. Of particular concern is the prospect of unknown but potentially significant changes to dam inflows such that the onset of water restrictions becomes more unpredictable and/or extreme.

Increasingly, stated preference techniques are being employed to assist research into valuing the welfare impact of policy responses in the context of urban water planning (see, for e.g. Hensher et al. 2006; Cooper et al. 2011; Brennan et al. 2007). Cooper et al. (2014) explores the effect of contextual factors on WTP from a contingent valuation experiment and concludes that the context or the 'backdrop to the experiment' is important. More specifically, Cooper et al. (2014) investigate the significant changes in WTP to avoid water restrictions when studies are administered against distinctly different climate backgrounds; namely during a prolonged drought versus during a succession of wetter years. Accordingly, one of the challenges is to find ways that produce a response in stated preference techniques which is nonetheless grounded in the real context which could include surplus water in times of non-drought. A key contribution of the current study is demonstrating how attributes for a choice experiment can be developed in a way that is sympathetic

to the needs of water planners to encapsulate uncertainty and yet also accurately describes the contextual setting.

This paper reports the results of a choice experiment conducted in a major city in eastern Australia. The primary purpose of the experiment was to estimate the non-market community values for specific attributes associated with the outcomes of drought response measures. This information was sought to understand the community's willingness to pay (WTP) for water security and used a novel approach to convey the risks of limited supply. A second goal was to identify how these values differ across attitudinal and spatial segments and socio-demographic (e.g. income) groups. This included investigating if those who have previously invested in technical water use efficiency or have access to recycled water also had differing WTP. The results provide insight into the extent that WTP indicates benefits that would alter the cost effectiveness of the water supply management strategy for delivering the city's water security objectives. The findings also confirm earlier concerns about the consistency of estimates gained from stated preference techniques when measurement takes place in a higher rainfall context.

The paper is divided into six parts. Section 2 provides an overview of the challenges of water planning under uncertainty and its relationship to the framing of Choice Models. In section 3, the design and sampling for this study are presented before briefly outlining the theoretical grounding of the choice experiment. The findings of the choice experiment are discussed in section 5 along with a brief description of customer classes. In section 6, key findings are discussed before offering some concluding remarks.

2. Water planning, uncertainty and framing choice experiments

Deciding on the optimal portfolio of water supplies for a city is no simple task. On the one hand cost minimisation would see alternative sources ranked from low-cost to high-cost with the former being exploited prior to the latter. However, the 'order-of-economic-merit' approach does a poor job of taking account of supply reliability. More specifically, rainfall-dependent supplies, like dams, are often cheaper but can be less reliable in some settings. Smaller storages that deplete rapidly are particularly susceptible and stand in contrast to technologies like desalination, which is generally more costly but not dependent on rainfall.

The attractiveness of technologies like desalination can also be shaped by the political environment and the pressure to be seen to respond to voters concerns about 'running the city dry'. In this context the Productivity Commission (2011) found that planning during the millennium drought was characterised (amongst others) by:

“large investments in rainfall-independent supply capacity, usually associated with highly politicised decisions and/or consideration of a limited set of options” (p. XIX)

The Commission subsequently urged for the use of planning techniques that were less deterministic and that could better deal with uncertainty.

The Productivity Commission illustrated one method incorporating uncertainty using real options (see, Productivity Commission 2011) whilst others have shown that broader heuristics can also be invoked to better deal with the inherent uncertainties of relying on rainfed supplies (see, for instance, Clarke 2014). Whilst attractive from an analytical standpoint, it is a major challenge to translate these approaches into choice models used to establish the WTP for different supply reliabilities.

One way to incorporate a degree of uncertainty in the design of a choice experiment is to place less emphasis on the historical data (i.e. the historical incidence of drought) as the basis for estimating the probability of drought restrictions on households. For example, the scenario in the status quo in the experiment could be adjusted for different participants so that the probability of drought differed. In effect this would amount running separate choice models to establish the impact of the likelihood of drought on WTP to avoid it. The advantage of this approach would be that the water planner, armed with these data, could then test different augmentation scenarios where the prospect of drought could be adjusted up or down, and thus better analyse staged augmentation decisions as additional information comes to hand. This approach allows the planner flexibility to test augmentation alternatives (or portfolios of alternatives), and to contemplate the values of deferring decisions, because she is aware of the welfare losses at different probabilities of drought. However, this approach itself assumes that the past climate is a reasonable predictor of the future trajectory of rainfall reliability.

Notwithstanding the benefits to the planner from not specifying the probability of drought restrictions in advance, respondents likely need some information upon which to assess the benefits (or costs) of facing different water restriction regimes. Thus, for this experiment we sought to use historical data to approximate the duration and severity of restrictions *once water restrictions had been triggered*, without framing this choice in the context of a defined probability of restrictions needing to be invoked.

Arguably, this represents a compromise insomuch as the severity of restrictions within the status quo are based on historical data but the likelihood of actually encountering any water restrictions at all has been left unspecified.

The approach nonetheless allows the analyst to generate estimates of the cost (or benefit) of alternative trajectories, once water restrictions are initially activated. These trajectories encapsulate differing severity of restrictions, each of which has a identified probability of occurring. The probabilities can be described to respondents and households can thus judge the extent to which they are willing to pay to change the likelihood of experiencing one of those states.

It is important to understand that in this case households are indicating what they are willing to pay to avoid the behavioural constraints placed upon them. The fact that the probability of facing these constraints is included in the experiment helps respondents understand the likelihood that the constraint will be more or less severe once drought restrictions are triggered.

3. Survey design and sampling

3.1 Survey development

This research adopted the general experimental design process for choice experiments developed by Hensher et al. (2005), comprising focus interviews, focus groups, survey pretesting and development of an efficient design. This process was structured to identify the attributes of the 'product', namely water supply security, and relevant attributes and levels. The sample was comprised of residents from a city in eastern Australia.

To assist this study a steering committee was formed comprising representatives from relevant government departments and water corporations. The committee members provided details of the context of the research and also became the vehicle for accessing technical expertise that related to the operational dimensions of water supply in the region.

Six focus groups, each comprising six individuals were undertaken at the beginning of March 2013 to explore the perceptions and attitudes of different population segments. The main purpose of the focus groups was to: Identify possible attributes in a Choice Model aimed at establishing a WTP to avoid water restrictions; Clarify the nomenclature of attributes (e.g. using the word 'tariff' versus 'water bill' etc.); Identify potential levels for attributes; Explore related concepts and ideas that might influence the conduct of the choice experiment.

The assembled information from focus groups and in-depth interviews was subsequently employed to develop a draft survey instrument. Two piloting exercises were undertaken: one using small in-person focus groups to establish the cognitive demands of the survey and to refine the wording employed, and the second exercise employed an on-line version of the survey to improve the statistical design. The on-line pilot comprised 54 respondents with the aim to inform the *efficient design* for the main survey.

3.2 The stated preference experiment

The main survey instrument comprised four parts: Part A had questions about water-related behaviour and sought opinions about water restrictions; Part B presented different water reliability options once drought is triggered and sought choices from respondents (i.e. the Choice Model); Part C sought detailed opinions about different types of water supplies and endeavoured to establish if these would modify the respondents' WTP; Part D included questions about respondents' socio-economic standing and additional opinions on environmental values, including attitudes to the introduction of permanent water wise rules.

The choice sets in Part B were designed around three attributes: (1). the severity and likelihood of water restrictions; (2). the maximum possible duration of MEDIUM and HIGH water restrictions; and (3) the impact on household water bills. Severity was described in line with the draft water restriction rules developed for the region. Likelihood was presented as a percentage chance of experiencing a particular level of water restriction.¹

Both severity and likelihood were combined into a unified visual 'meta' attribute. As already noted, the status quo for this attribute was devised by imposing a starting point on water storage – namely the point at which drought restrictions are initially triggered. In order to generate estimates of the likelihood of experiencing a particular type of restrictions a large number of hydrological simulations (100,000) were run by the dam managers responsible for water provision using the state government's hydrological model of the region. The simulations were over a period of six consecutive years and the frequency with which the various levels of restriction were triggered was recorded. A six year timeframe was selected as the most plausible period for considering the progressive depletion of the water storage and coincided with the period before significant intervention by the state was likely in order to modify water access (e.g. the time before the state would construct a pipeline or similar to avoid ongoing political costs). The percentage measure in the status quo corresponded with the likelihood of experiencing each of the different levels of restrictions over that time frame, rather than signifying the portion of time over the six year period that a particular restriction level would be in place. For example, if high level restrictions have a 5 per cent chance of being experienced this means that, once drought restrictions have been triggered, there is a 1 in 20 chance that restrictions will be escalated to the most severe level of constraint at some point in the following 6 years. This was done in an effort to isolate the second attribute – the duration of water restrictions.

The duration of water restrictions was depicted in months, with improvements represented by a decrease in the maximum time residents would be forced to behave as specified by the restriction rules. The rationale for including this as a second attribute was twofold:

1. possible usefulness for water planning purposes, especially in the context of understanding the costs related to deferring augmentation projects (e.g. does holding WTP and thus

¹ Care was taken to describe the probability of 'experiencing' a level of water restriction – specifically, it was emphasised that a 50 per cent chance of experiencing a level of water restriction did not mean that it would occupy half the time available.

welfare losses increase over the period of time for which behaviour is constrained, thus building a case for actively modifying supply investment decisions) and;

2. information from the focus groups, where participants had noted that the duration of dry periods was a key defining feature of drought from their perspective.

The status quo in this case was set at six years on the grounds that it was highly unlikely that any drought event would go beyond this timeframe and technological interventions, if chosen, could be expected to take this amount of time to complete (as noted above).

The impact on water bills was the chosen payment vehicle and represented the third attribute. This was a plausible payment option and the maximum annual price was set at \$510, with households making equal payments every 4 months to coincide with the water utility billing cycle. Given that the augmentation works would necessarily take place over a number of years, the payment was described as being made every 4 months over a 4 year timeframe.²

In total, respondents were required to review 6 choice sets where the SQ appeared first. The attributes and their levels are reported in Table 1.

² There was a view that households were familiar with paying for water-related infrastructure over this time period. Also, it is not necessary for each attribute to be framed with equivalent time periods. Converting various dollar amounts to net present value allows comparison, regardless of timeframe. In this case different time periods (6 years for the first two attributes and 4 years for the third) resulted from efforts to use plausible scenarios in the experiment.

Table 1 Attributes and levels used in the choice sets

Attribute	Descriptor	Status Quo	Levels
Severity and likelihood of water restriction	The proportion of hydrological model runs when restriction levels are triggered	27% chance of None, 47% chance of Low, 21% chance of Medium, 5% chance of High	27%, 32%, 49%, 74%, 79%, 95% None 0%, 30%, 47%, 52%, 68%, 73% Low 0%, 21%, 26% Medium 0%, 5% High
Maximum time in restrictions	Maximum time on Medium or High restrictions (months)	20 months	0; 1; 2; 3; 20
Impact on water bill (\$)	Additional fee on water bills per annum (paid three times per year) for four years	0 per annum	15; 45; 75; 120; 240; 510


















Here we have used an s-efficiency design criteria, that minimizes the sample size needed to identify the parameters. This requires estimates of priors for the parameters, which we derived from a MNL model estimated on the data generated from the pilot survey (see, e.g. Scarpa and Rose 2008).


In generating the designs a number of constraints were imposed on the levels that each of the attributes could take in combination with other attributes. Thus, the probability of being on MEDIUM restrictions could only increase to 26 per cent if the probability of being on HIGH was simultaneously reduced from 5 to 0: i.e. the overall risk profile could only improve. Similarly, the probability of being on LOW could only increase if there were commensurate falls in the probability of either MEDIUM or HIGH. The sum of the probabilities across all states was constrained to equal 100. Because DURATION was defined only in terms of HIGH or MEDIUM restrictions, DURATION was set to zero for scenarios where the probabilities of HIGH AND MEDIUM were equal to zero. Otherwise it always took a non-zero value. These constraints were imposed as part of the efficient design algorithm. This was dealt with within *Ngene*³ by specifying a number of restrictions on the levels, and combinations of levels (the *Ngene* code employed is available from authors on request).


³ *Ngene* is an econometric software program designed to estimate stated choice experimental designs.

To better understand the utility that relates to each level of water use restriction we provide below (Figure 1) the summary information offered to respondents when framing their choices. A sample choice set is also provided as Figure 2.

Figure 1: Summary of water use impacts associated with each level of water restriction

	OUTDOOR WATER USE NOTE: Public parks, gardens and playing fields must also comply.					
LEVELS	Sprinklers or other watering systems	Hand-held hoses with a trigger nozzle	Vehicle washing	Hosing of hard surfaces	Filling of new or renovated pools greater than 10,000 litres	Filling of existing pools, spas and fountains
HIGH						
MEDIUM		2 days/week (5pm–9am)	Bucket only			Bucket only
LOW		3 days/week (5pm–9am)	5pm–9am	Limited		Hose only
NONE						

 = Total ban on use

 = No ban on use

2 days per week = can only use water for this activity 2 days per week during the hours 5pm–9am.

3 days per week = can only use water for this activity 3 days per week during the hours 5pm–9am.

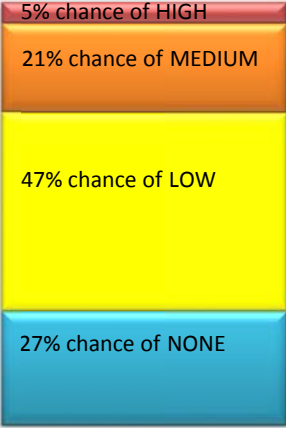
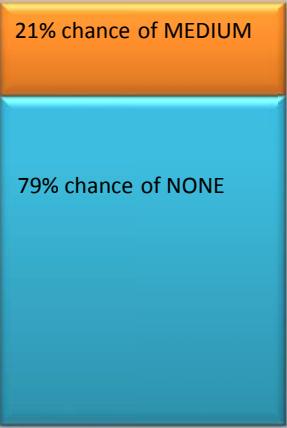


Bucket only = watering for this activity can only be done with a bucket.

Limited = building facades and windows may be washed during designated hours only.

Hose only = watering for this activity can only be done with a hose fitted with a trigger nozzle.

5pm–9am = watering for this activity can only be done during the designated hours of 5pm–9am.

Figure 2 A sample choice set

	Option 1: current situation	Option 2: improved water supply availability
Likelihood of each level of restrictions		
Maximum duration of MEDIUM and HIGH water restrictions 	20 months	20 months
Total extra cost per year for 4 years (paid on water bills) 	\$0	\$45 per year (equal to \$15 every 4 months)
WHICH OPTION WOULD YOU CHOOSE?	<input type="checkbox"/>	<input type="checkbox"/>

3.3 Sampling and sample characteristics

Sampling was conducted using a proprietary on-line panel of potential respondents. Postcodes were used to define the limits of the sample, in an effort to ensure the sample was drawn from geographically dispersed customers. The main questionnaire was opened to respondents on 20th June 2103 and closed on 12th August 2013 yielding 412 completed responses. This represents a response rate of 13.1 per cent relative to the total number of households initially invited to respond (excluding individuals screened out).

There are potential biases associated with any data collection method, including online approaches. In the case of on-line Choice Modelling there are also a number of additional advantages including cost-effectiveness, accuracy and speed of data collection (Fleming and Cook 2007). Details of the sample are reported in Table 2.

Table 2: Socio-demographics of the survey sample and population

Variable	Sample	Population*
Median Age	40-44	50-54
Owned home outright	25%	35%
Male	28%	50.2%
Completed a tertiary degree	37%	7.5%
Have an outdoor pool or spa	23%	12%
Have a lawn and/or garden that requires watering	78%	75%
Median Household income before tax	\$78,000-\$103,999 per annum	\$65,000-\$77,999 per annum

*Source: Australian Bureau of Statistics (2013)

A χ^2 test was used to determine if the sample is representative of the general population. The test revealed some significant differences at the 5 per cent level between the sample and the general population. More specifically, the sample comprised more women relative to the population, or at least females were more inclined to complete the survey on behalf of their household. The

household income of the sample was higher than the population and there was a higher representation of middle-age respondents in the sample.⁴ The level of education was significantly higher in the sample than the population and fewer households owned their home outright compared to the population. Pool ownership was significantly different between the sample and population although the sample and population had similar ownership of gardens requiring reticulated water. Although response bias was evident, it was not unexpected given the context of the study and the mode of data collection.

4. Model specification: Latent class models

4.1 Background

Individual heterogeneity can be accounted for in a number of ways in discrete choice experiments. Observed personal characteristics (age, gender, etc.) can be used as determinants of the marginal utility of attributes (i.e. observed heterogeneity). Alternatively, it is possible to assume that marginal utilities are not fixed across the sample, but follow some distribution(s), and model these as random parameters (McFadden and Train, 2000). An alternative is the latent class model (LCM), which assumes that there are a finite number of classes of people, each with different preferences. The distribution those preferences take within the sample is not imposed (Train, 2009 p.135), which is an advantage compared to the random parameter approach.

In the LCM, the probability that individual i selects alternative j from the set of options N , in choice situation t , conditional upon being in class c (and that the conditional logit specification is appropriate), is given by:

$$P(y_{it} = j|c) = \frac{\exp(\lambda\beta_{ck}X_{ijkt})}{\sum_{n=1}^N \exp(\lambda\beta_{ck}X_{inkt})} \quad (1)$$

where $\beta_{ck}X_{ijkt}$ is the systematic element of utility based on attribute vector X and marginal utilities identified by the parameters β . The scale parameter λ is defined by its relationship with the variance of the random term:

⁴ The exclusion of the <18 group accounts for the under-representation of younger cohorts although the >70 group were also under-represented in the sample.

$$\lambda^2 = \frac{\pi^2}{6\sigma^2} \quad (2)$$

The beta parameters are class specific. As the number of classes C increases, the flexibility of the latent class framework to represent heterogeneity increases. Statistically, there will be limitations to the number of classes that can be reliably identified. For a given number of classes C , if the probability of individual i being a member of class c is given by S_{ic} , then the unconditional probability of individual i making a sequence of choices across T choice sets is:

$$P(y_i) = \sum_{c=1}^C S_c \prod_{t=1}^T P(y_{it}|c) \quad (3)$$

The choice of C is typically an empirical issue. A number of information criteria⁵ can be used to identify the appropriate number of classes (Hole, 2008; Nylund et al., 2007). Class membership for an individual is not imposed *ex ante*, but instead is treated probabilistically, although, the probability of class membership can potentially be made a function of the individuals observable attributes.

The modelling strategy adopted here is to identify the appropriate latent class structure without reference to individual characteristics, and then in a second stage use individual specific covariates to explain the probability that individuals are members of particular classes.

4.2 Coding of variables and data analysis

The ‘water supply availability’ attribute comprised three variables associated with the level of restriction imposed (i.e. high, medium, and low) each of which could take a number of values coded using the associated probabilities in the design. The baseline for this attribute (i.e. no water restrictions) was omitted in estimation due to collinearity with the levels in the three variables. This, the marginal value associated with a change in the probability of a particular level of restriction being applied should be interpreted as a shift in the probability from that level to no restrictions.

⁵These include Bayesian Information Criteria (BIC), Akaike Information Criteria 3 (AIC3) and Consistent Akaike Information Criteria (CAIC).

A number of covariates were also used in the reported model to explain class membership. Table 3 provides a list of the covariates and the coding structure used for each.

Table 3 Coding of variables to explain class membership

Water Wise Rules Attitudes* (WWR)	Respondents' attitudes towards water wise rules (scale items developed from focus groups and piloting 2013).	Factor score derived from 7 scale items Mean=0, SD=1
Water Restrictions Attitudes (WREST)	Respondents' attitudes towards water restrictions (scale items developed from focus groups and piloting 2013; adapted from SEQ report).	Factor score derived from 8 scale items Mean=0, SD=1
Pool or Spa (POOL)	Whether respondents have an outdoor pool or spa	Yes = 1 No = 0
Gender (GENDER)	Gender	Male = 1 Female = 2
Duration of residence (LONG)	How long respondents have lived in the Lower Hunter region	Less than 5 years = 1 Between 5 and 10 years = 2 More than 10 years = 3
Access to alternative water supply sources (SUPPLY)	Household access to sources of water: SUPPLY1 = Recycled water SUPPLY2= Groundwater (e.g. bore, spring) SUPPLY3=Rainwater tank SUPPLY6=None	Yes = 1 No = 0

*WWR represent modest constraints on water use (for example, no hosing of hard surfaces permitted; watering systems and hoses can only be used before 10am and after 4pm) that could apply permanently. Such rules do not presently exist in the study site and an attitudinal question was included in the survey to assess support for WWR.

5. Results

5.1 Determining class size

As outlined in section 4, in estimating latent segment models the number of classes, *C*, cannot be predefined. Accordingly, *C* must be imposed by the analyst and statistical criterion employed to choose the 'optimal' number of segments in a set of estimations. Here, two criteria were used to assist in establishing the size of classes, namely the Bayesian Information Criterion (BIC) and Consistent Akaike Information Criterion (CAIC) (AIC measures failed to identify an optimal class

structure in any model). Swait (1994) advises that these criteria should be used as a guide to determine the size of C and conventional rules for this purpose do not exist. Thus, judgement and simplicity play a part in the final selection for the size of C. The three preference class model reported here had the lowest BIC (1803.906) and CAIC (1823.906) compared to the other class structures and a pseudo R^2 of 0.524.

5.2 Model results

35 per cent of the respondents were identified as ‘protestors’ and removed from modelling.⁶ To be identified as a protestor, two criteria had to be met. Firstly, the respondent had to select the status quo (no change) option in all 6 choice sets. All respondents who met that condition were then screened against the debriefing questions about why they made that selection. Some reasons do not meet the criteria for classification as a protestor (e.g. “I would like to have improved water supply availability, but cannot afford to pay anything for it” suggests the respondent has considered all options, but the increase in cost exceeded their reservation price). Subsequently, 268 respondents remained for further modelling.

Table 4 reports the estimated results for the preferred latent class model, a three preference class model. The first part of the table (utility function: estimates) reports the parameters and significance of attributes in each of the three preference classes compared to the base levels. The second part of the Table 4 (Estimated probability of class membership) reports the posterior means of the probability of class membership across the sample. In this case, about 51 per cent of the modelled sample makes up class 1, 40 per cent form call 2 and around 8 per cent form class 3.

⁶ This may appear high. However, given the context of the experiment (i.e. a region with relatively high reliability of supply and limited exposure to drought) we consider this plausible.

Table 4: Estimates for a 3 class latent class model

	Class 1		Class 2		Class 3	
Utility function: estimates						
	coeff	Se	coeff	se	coeff	se
COST	-0.056***	0.008	-0.035***	0.004	0.018*	0.010
HIGH	-0.154***	0.055	-0.112**	0.058	0.235*	0.130
MEDIUM	-0.059***	0.016	-0.018	0.014	-0.091	0.059
LOW	-0.012**	0.006	-0.003	0.006	-0.047**	0.023
DURATION	-0.027	0.018	-0.024*	0.015	-0.079**	0.033
STATUS QUO	-0.058	0.334	-2.732***	0.453	1.897	0.960

Estimated probability of class membership

	Class 1	Class 2	Class 3
Total	0.513	0.403	0.082

*, **, *** indicate p-values less than 0.1, 0.05, 0.01 respectively

In preference class 1, individuals held positive preferences for reducing the risk of their city experiencing HIGH, MEDIUM and LOW level outdoor water restrictions. As we have noted this class represented approximately 51 per cent of the sample. Preference class 2 represented approximately 40 per cent of the sample and individuals in this class also held positive preferences for reducing the risk of their city facing HIGH water restrictions, but not for changes in any other levels.. This class also favoured a reduction in the duration that their city would be on MEDIUM or HIGH water restrictions, although this was not significant at the 5 per cent level.

Interpreting the behaviour of individuals in class 3 is problematic, as this group has a positive coefficient on COST and HIGH restrictions, but apparently the group valued a reduction in LOW restrictions. There are several plausible explanations for this outcome. First, it is possible that this group did not fully understand the choice framework. Second, it is possible that this group were using the opportunity to express some form of protest against the subject matter of the experiment. Previous experiments of this form have identified that there are some sections of the community who hold quite strong and possibly conflicting views on water restrictions; ranging from the notion that restrictions necessarily build community esprit de corps though to restrictions being an infringement on civil liberties (see, Cooper, Burton and Crase 2011). Class 3 might thus represent a group who cannot rationalise water restrictions in the context of a payment vehicle. Notably, this class represents a relatively small group (8-9 per cent) of respondents.

Class membership was estimated using a second stage fractional multi-nomial logit (MNL) model, based on the allocation of individuals to the most likely class, based on the results in Table 4. This model preserves the constraint that all class probabilities have to be non-negative, and sum to unity for any individual. This ostensibly allows us to identify if there are significant relationships between class membership and other parameters. Table 5 reports the associated marginal effects (which are more informative than the parameters) that can be derived from the fractional MNL model of preference class membership.

Table 5 Latent class membership

	Class 1		Class 2		Class 3	
Latent class membership: marginal effects						
	coeff	Se	coeff	se	coeff	se
WWR	-0.054	0.042	0.024	0.040	0.030**	0.014
WRESTR	-0.007	0.043	-0.046	0.041	0.053***	0.015
GENDER	0.147**	0.064	-0.102	0.062	-0.045	0.024
POOL	-0.153**	0.072	0.170**	0.069	0.017	0.031
LONG	0.086**	0.041	-0.086**	0.040	0.001	0.017
SUPPLY1	-0.058	0.133	0.109	0.137	-0.050**	0.023
SUPPLY2	0.034	0.160	0.033	0.159	-0.067***	0.015
SUPPLY3	-0.030	0.138	0.127	0.141	-0.098***	0.032
SUPPLY6	0.083	0.155	0.188	0.148	-0.271	0.178

** ,*** indicate p-values less than 0.05, 0.01 respectively

By definition, the sum of coefficients across the 3 classes is constrained to sum to zero

A set of attitudinal and socio-demographic variables significantly explain preference class membership. More specifically, these variables have a significant marginal effect on the probability of class membership.

In the case of class 1, the gender (GENDER) of the respondent, whether the respondent has an outdoor pool or spa (POOL) and the duration of residence in the study location (LONG) significantly explain membership of this class. More specifically, female respondents, those with no outdoor pool or spa, and those that have lived in the study location for longer have a higher probability of class membership for Class 1, relative to others in the sample.

Alternatively, in preference class 2, the probability of class membership is increased if a respondent has a household with an outdoor pool or spa (POOL) and has lived in the study location for a shorter duration.

Stronger preferences for water wise rules (WWR) tend to increase class membership for class 3. In addition, those with negative attitudes towards water restrictions (e.g. too costly, unfair, pointless) are also more likely to be in class 3. Moreover, respondents who do not have access to recycled water, groundwater (e.g. bore, spring) and rainwater tanks are also more likely to be a member of this class. The mixed nature of these variables again supports the view that this class is best regarded as a mix of protest respondents.

Table 6 presents estimates of marginal effects for the different attributes. Respondents' preferences are described in terms of their WTP for changes in the levels of the attribute compared to defined base levels. For example, if the probability of a water restriction is reduced, the probability of "no restriction" is increased equivalently). It would also be possible to estimate the value for shifting to a lower level of risk, rather than complete removal.

The values reported in Table 6 are the median values of distributions derived from 10,000 simulations of parameters drawn from the estimated parameter and variance covariance matrixes (Krinsky and Robb 1986), and then the WTP generated as the conventional ratio.

Table 6 Willingness to Pay (\$/house/year) for a 1 per cent reduction in the probability of a water restriction of that level being imposed (and a 1 per cent increase in probability of no restriction).

	Class 1	95% Confidence Interval	Class 2	95% Confidence Interval
High	+2.72***	1.039-4.406	+3.16**	0.581-5.742
Medium	+1.05***	0.589-1.512	+0.51	-0.178-1.214
Low	+0.22**	0.037-0.395	+0.07	-0.210-0.357

*, **, *** indicate p-values less than 0.1, 0.05, 0.01 respectively

As we have noted respondents belonging to preference class 1 have positive preferences for a reduction in the probability of experiencing HIGH, MEDIUM and LOW water restrictions. Willingness

to pay is positive and significant at the 95 per cent level of confidence (or greater) for this class. For example, respondents in this class, on average, are willing to pay \$2.72 for a 1 per cent reduction in the probability of experiencing HIGH water restrictions during drought. Positive preferences for a reduction in the probability of HIGH water restrictions are apparent for respondents in class 2. At the 95 per cent level of confidence this group is willing to pay \$3.16 for a 1 per cent reduction in the probability of experiencing this level of restriction in drought, on average. In the case of class 2 the lower bound willingness to pay is \$0.58 and the upper bound is \$5.74 for removing a 1 per cent chance of experiencing HIGH water restrictions.

The estimates suggest that participants in class 1 are willing to pay, on average, approximately \$13.60 (i.e. $\$2.72 \times 5$) per annum for 4 years to remove the 5 per cent probability of experiencing HIGH water restrictions, as described in the 'status quo', such that there are no water restrictions of this form. More specifically, participants in class 1 are willing to pay approximately \$13.60 per annum for 4 years to move from a scenario where the likelihood of facing water restrictions is 5 per cent for HIGH; 21 per cent for MEDIUM; 47 per cent for LOW; and 27 per cent for NONE to a scenario where the chance of facing HIGH water restrictions is 0 per cent; but remains at 21 per cent for MEDIUM; 47 per cent for LOW and is thus 32 per cent for NONE (the risk of facing HIGH restrictions has been shifted to the NO restriction category).

Alternatively, class 2 individuals are on average willing to pay approximately \$15.80 ($\3.16×5) per annum for 4 years to remove the 5 per cent probability of facing HIGH water restrictions, and move that probability to no water restrictions.

The estimates in Table 6 can also be used to determine the willingness to pay to remove the chance of experiencing all levels of water restrictions. In addition, it is possible to estimate the trade-offs that respondents within this class will make between the risks of experiencing different levels of water restrictions.

The willingness to pay for a reduction in the duration of time the city faces MEDIUM or HIGH water restrictions is not significant at the 95 per cent level of confidence.

Clearly, these findings suggest that ‘increased water availability’ options are valued by particular segments of customers. Importantly, the empirical estimates can be adjusted to inform water augmentation decisions in a way that is conducive to adaptive management and planning when there is uncertainty.

6. Discussion and concluding remarks

This study sought to investigate households’ WTP to avoid behavioural restrictions placed on water use during drought. The particular focus was to generate WTP estimates that could inform more adaptive decision-making.

Recall that respondents were asked to make choices as if they were entering a drought restriction period. Our rationale for taking this approach was that the resulting estimates would then be grounded in a scenario that could be adjusted by the planner as additional information came to hand without the need for additional choice experiments to enumerate household welfare. For example, with these data the planner can estimate the community benefit of avoiding different severities of water restrictions and then compare this against the cost of alternative portfolios of supply with differing reliabilities.

The limit of this approach is that the water planner then needs to match hydrological information to the drought trigger scenarios. Because this type of planning can be costly and because some larger projects can be staged, these Choice Modelling data are most useful for fine-tuning the deployment of the more costly components of the water supply portfolios. For instance, the WTP estimates could feasibly be integrated with the impacts of large-scale projects on hydrology/water restrictions while varying the water in storage. This might then allow the planner to optimise the deployment of various stages of a project against the water in storage.

The study found that there was a positive WTP to avoid drought restrictions and that this varied with the nature of the behavioural constraints. More severe restrictions attracted a higher WTP than less severe restrictions, on average.

The choice experiment revealed that the preferences for paying to alleviate water restrictions were heterogeneous. A sizeable portion of the sample appeared to protest against the notion of paying to reduce the risk of water restrictions. Nonetheless, our estimates of the total welfare gains from eliminating water restrictions are also significant.

The welfare estimates generated by this experiment raise questions about the extent to which these data support the introduction of more severe or more frequent water restrictions. It is important to note that the data collected for this experiment were framed as ‘willingness to pay’ which aligns with consumers making a payment to secure an improvement in welfare (as symbolised by a reduction in water restrictions). In that regard the data provide a basis for comparing investments that would reduce the need for water restrictions. Thus, modest willingness to pay for reducing water restrictions should not be used to advocate for more stringent or more frequent water restrictions. Rather, modest willingness to pay simply limits the case for measures that alleviate the need for restrictions.

The assembled data have primarily been used to answer questions about the cost effectiveness of water portfolios. Nonetheless, more could be made of this information, including more detailed analysis of the motivations that shape willingness to pay and the nature of protest in this context. Another important extension would be to test the assumptions that allow for the wider use of these data. This could include investigation of any links between willingness to pay and willingness to accept in this setting.

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