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Exploring customer heterogeneity with a scale-extended latent class choice model: Experimental evidence drawn from urban water users

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Abstract

The search for improved water pricing is central to urban water reform in many countries. Establishing efficient water prices is notoriously difficult, not least because different customers have different demands for water and yet they are presently faced with a one-size-fits-all approach to pricing and service. This is especially challenging where water availability fluctuates widely, as is the case in many parts of Australia, because the impacts of exposure to episodic periods of scarcity can differ markedly. There is now substantial interest in the notion of 'unbundling' the water product to provide a better fit between customers' preferences and the level of service received. Following this trend, this study provides important insights into householders' willingness to pay for a range of flexible water options using a choice experiment. The paper reports a relatively underemployed extension to the latent class modelling framework to investigate preference heterogeneity towards urban water products, including purchasing services that involve the provision of environmental and amenity outcomes. The work adds to studies that use choice data to reveal heterogeneity while improving our understanding of household customers' demands. Overall, it also brings into focus questions about the future management of water in urban contexts.

KEYWORDS

choice modelling, scale-extended latent class model, urban water, water pricing, water restrictions, waterway health, willingness to pay

JEL CLASSIFICATION

Q25, Q51

1 | INTRODUCTION

An increasingly common government response to extended droughts in urban areas is the imposition of mandatory water restrictions that prohibit particular types of water use by households and businesses. This approach has attracted the attention of numerous economists concerned about the efficiency implications and especially as it gives rise to differing economic impacts across various water users (Cooper et al., 2018, 2011; Edwards, 2008; Grafton & Ward, 2008). The reaction to these criticisms, coupled with research by groups like the Productivity Commission (2011) and the National Water Commission (2011), has progressively encouraged monopoly water utilities to show greater interest in shaping services that account for customer heterogeneity. In Victoria, Australia, for instance, the economic regulator with oversight of water utilities has taken this to a new level and openly challenged utilities in that jurisdiction to better define the outcomes that customers want and to match the services they provide accordingly (ESC, 2008).

Preferences for water use and water services are likely to vary across households and firms. For example, some households will have existing water-dependent assets, like gardens and swimming pools, and be reluctant to see these deteriorate, even when general water availability declines (Howe et al., 1994). Similarly, some businesses will use processes where water is a critical input to production and be willing to pay more to retain supply, rather than facing restrictions on water access/use. Some customers might also be intrinsically inclined to support using water for public good provision during a drought, and others might be more sceptical.

Studies that focus on water customer heterogeneity usually emphasise different 'drivers' of water use preferences (Arbués et al., 2003; Renwick & Green, 2000) rather than understanding the willingness of customer groups to pay different prices for different services. The size of the household, structure of dwellings and climatic factors have emerged as important influences on water use, along with income (Hoffman et al., 2006). Most of these studies have been prompted by water shortage and undertaken at a time when households are expected to conserve water. In a separate line of inquiry, a body of work has progressively emerged that explores how customers might also willingly contribute to public good provision or opt for alternative water supplies by paying additional water charges (Bennett, McNair, & Cheeseman, 2016; Edwards et al., 2020).

In terms of meeting customers' expectations, a key consideration for any water utility is the size of different customer segments and the relative strength of preference that is tied to that segment. A portion of customers might have a desire to avoid restrictions on their water-using behaviours, but there are also likely to be variations within this cohort about the strength with which that view is held. Thus, if only a small proportion of customers seek to avoid restrictions, then the case for more tailored responses around this is weakened. Likewise, even if a large portion would prefer to avoid restrictions, but are unwilling to pay substantially for the change, then a utility will find it more challenging to warrant a nuanced offer to customers. This paper addresses these practical challenges and also adds significantly to the literature on urban water management by reporting the size of different customer segments and the strength with which preferences are held within segments.

This paper reports the results of a choice experiment that was administered to specifically explore customer heterogeneity in Australia's two largest cities, Sydney and Melbourne. The experiment was undertaken to establish water users' willingness to pay to offset different levels of water security and used a visualisation approach to characterise the risks associated with supply constraints formerly developed by Cooper et al. (2018). Specifically, risks and the severity of different water restrictions were graphically represented as part of the choice experiment. However, unlike Cooper et al. (2018), this choice experiment also included water-related public goods, such as environmental benefits and community amenities, and asked participants to pay for these through additional water charges. Accordingly, the paper adds to the literature on holistic management of water demand in urban contexts and also highlights the multiple expectations that customers have increasingly developed of their water suppliers (AWA, 2018). The results identify the division between customer classes and points to the challenge of designing one-size-fits-all tariffs, which remain the norm in most jurisdictions. The results also provide insights into management choices for urban water utilities, such as estimating the possible customer demand for nonrainfall-dependent water supplies, like desalination or recycled water, and how this might also form part of a portfolio of supplies that provide multiple benefits. The results also highlight the potential for a water service that allows customers the option of simultaneously securing environmental outcomes through additional payments.

2 | A SYNOPSIS OF WATER MANAGEMENT IN AUSTRALIA AND THE STATUS OF THE LITERATURE ON WILLINGNESS TO PAY FOR WATER SERVICES

Water management has come into sharp focus during the extensive water shortages associated with the 'Millennium drought' in South Eastern Australia—between the late 1990s and 2010—and the subsequent drought that covered much of Australia from early 2017 to 2020. In addition, ongoing discussions about the impacts of climate change make water management a perpetual topic of debate with CSIRO (2020) noting with high confidence that '[t]he time in drought is projected to increase over southern Australia'. During the Millennium drought, surface water availability for Australian cities declined markedly, with major urban centres like Sydney and Melbourne forced to ration supplies. Melbourne's water storage had fallen to about 30% of capacity by 2008 and Sydney had around 40% water availability in 2007 (Melbourne Water, 2008; Sydney Catchment Authority, 2013). Sydney's water storage was again at record low levels at the end of 2019, prompting the state government to progressively tighten restrictions on outdoor water use throughout that year (Hannam, 2020). Between these two droughts, very limited progress had been made on exploring how customers might react if they were given options, rather than facing universal water use restrictions and a standardised water service. Arguably, this reflects a proclivity to closely research water demand management during drought and then set it aside once it rains (see, Cooper et al., 2018).

Episodes of drought are often accompanied by intense debate about whether Australia's population growth is sustainable within extant natural resource limits (e.g. Allen, 2018). This politically charged environment is further complicated by the contrast between how water shortages are managed across different water-using sectors.

Generally, water shortages in agriculture are dealt with by a mix of market-based mechanisms, like water markets, and government support for agricultural businesses, through publicly financed drought relief. In contrast, environmental water use receives few concessions during drought. Rather, the natural environment is often assumed to be conditioned to cope with episodes of stress and this can even be presented as a bonus, by limiting the expansion of invasive species, for instance (Schumacher et al., 2008). Urban water use is managed during drought through a range of alternative mechanisms. These usually comprise a combination of demand reduction measures and bringing forward supply augmentation plans that are less reliant on rainfall. There are limits to the extent to which water suppliers can hold redundant capacity to buffer for drought (e.g. idle desalination plants), so there is always likely to be a place for some form of demand management in future.

Demand management can take the form of suasion and 'education' can be used to encourage more conservative use of water, but studies have shown that these impacts can be quite variable and context specific (Gilbertson et al., 2011). For instance, Pérez-Urdiales and Baerenklau (2020) note that the request from the Governor of California for voluntary water conservation realised only half of the targeted reduction. Demand reduction has also been encouraged in Australia through programmes aimed at subsidising households and firms to become more 'water efficient' and/or 'self-reliant' (e.g. installation of rainwater tanks and water-saving appliances). The final demand reduction approach hinges on the imposition of bans or limitations on specific water-using activities, like abolition of garden watering or restricting the hours when watering can take place.

One of the consequences of these approaches to demand management is that some urban water users have established strong psychological links between their own water use, water conservation and environmental and community amenity, even if the hydraulic links between these do not exist. That is, a legacy of successive campaigns to raise the so-called 'water literacy' is that some households relate their own access and consumption of potable water directly to a range of other water-dependent activities, like green public space or healthy streams, despite the fact that some streams are not used for potable supplies (Cooper et al., 2012). Nonetheless, these psychological factors have also seen water utilities being increasingly forced to transform from 'taps and toilets' business to organisations keen to present a wider perspective on environmental stewardship and holistic water management (see, e.g. AWA, 2018).

However, what is missing from this transformation is an understanding of how different customers value and understand the relationship between security for potable supplies, other water-related public goods and the prices paid for water services. Against this background, understanding the extent of heterogeneity of preferences is an important step in designing efficacious responses. Put differently, there would be little point in refining and offering different services, like options to pay for environmental benefits or an option for higher water security, if the demand for such services did not exist.

The literature on the willingness of customers to pay for improved water reliability and other water-related products draws primarily from regions where drought is more common, like Australia and western states in the United States. Nonetheless, mounting pressure on water supply provision due to population growth and climate change is also giving rise to studies on this topic in wetter climates (e.g. Dupont, 2013). A number of early studies sought to understand the implications of water use restrictions by looking at out-of-pocket expenses and these generally report modest imposts on households (e.g. Russell et al., 1970). Stated preference approaches were later published using contingent valuation (e.g. Howe et al., 1994) and choice experiments (e.g. Blamey et al., 1999). Hensher et al. (2006) used a choice model to also show that households in Canberra had a low willingness to pay for moderate water restrictions, but their estimates of willingness to pay increased substantially when the restrictions were more severe.

Cooper et al. (2019) reviewed several studies that focus on customers' willingness to pay to avoid water restrictions and noted variations in estimated willingness to pay. For example, Australian studies in the 2000s and late 1990s report household willingness to pay off between approximately A$150 per year and A$240 per year, while other US studies covering the same time period show willingness to pay estimates ranging from about US$55 to US$410 per year.

There are several explanations to the variations witnessed in estimated willingness to pay. First, the climatic setting of water restriction studies varies (drought versus nondrought) and Cooper et al. (2019) have shown that climatic context can be important in these types of analyses. Second, the nature of water restrictions themselves can differ across settings. In Australia, it is common for restrictions to be staged, although the behavioural constraints under each stage can vary across states and the duration is also driven by a change in the weather. In California's 2012–2016 drought, the State Water Resources Control Board imposed mandatory reductions across 400 water utilities in 2015; however, Mitchell et al. (2017) observe that meeting those constraints was more onerous on some customers than others, depending on the targeted consumption in each district. Third, the description of the price attribute in stated preference studies varies. For instance, Wilson et al. (2021) provided respondents the option of paying for improved water reliability through either a change in the volumetric rate, a shift towards inclining block tariffs or a fixed payment, while many other studies offer a simple monetary payment vehicle comprising a change to water bills for a specified timeframe (e.g. Cooper et al., 2019). Fourth, the combination of water supply reliability with other attributes—explicit and implicit—differs. Dupont (2013) considers customers' willingness to avoid water restrictions, although the experiment is premised on a scenario of consumers also accepting additional use of reclaimed water. Hensher et al. (2006) also include an attribute that sought to capture the ‘greenness’ of public spaces as part of their analysis of water restrictions in Canberra.

While stated preference studies on averting water restrictions have been progressively refined alongside the evolution of the related techniques, similar strides have been made around the valuation of water used for other public good purposes. Partly, this has been driven by interest in reassigning water to meet ecological ends, as occurred in Australia's Murray–Darling Basin, but there is wider international interest also evident (e.g. Pedroso & Biu Kung'u, 2019). Stated preference techniques have been used to estimate the ecological value of water by establishing willingness to pay for different attributes of ecosystems, such as river health (Windle & Rolfe, 2005), native birds and vegetation (Bennett et al., 2008) and changes in native habitat (Macdonald et al., 2015). While local streams and waterways have been the focus of some analyses (e.g. Brent et al., 2017), other studies have explored the willingness of households to pay to achieve more distant environmental changes. In this context, Windle and Rolfe (2005) showed that households in Brisbane would pay A$3.21 per year for a 1% improvement in the environmental health of the Fitzroy estuary in the Great Barrier Reef Catchment, over 1000 kilometres to the north. As with the stated preference studies on avoiding water restrictions, the strand of work on environmental and other values of water is characterised by substantial variations in estimates. Again, these can be attributed to substantial contextual differences, differences in the way environmental changes are described and alternative approaches to articulating the payment vehicle. In the context of the latter, common approaches include the use of a generic ‘government levy’ (e.g. Windle & Rolfe, 2005), payments to ‘trust funds’ (e.g. Bennett et al., 2008) and a specific increase in household water bills (e.g. Bennett, Cheesman, et al., 2016). This latter approach is arguably consistent with the earlier observation that water utilities are broadening their scope of responsibilities to deliver multiple water-related activities potentially of interest to customers.

3 | SURVEY DESIGN AND ADMINISTRATION

3.1 | Survey development and choice experiment design

This research followed the overall experimental design process for choice experiments established by Hensher et al. (2005), involving focus interviews, focus groups, survey pretesting and development of an efficient design. Initially, in-depth interviews were conducted with water industry experts from water authorities in both Sydney and Melbourne, such as regulation and planning managers, regulatory economists, and customer and financial services managers. Subsequently, eight group discussions were held with residents from the two cities of Sydney and Melbourne. These sessions lasted for 1–1.5 h and included 5–10 participants from community groups. The sessions explored participants' understanding of water use and water restrictions and their own water bills. Respondents were also encouraged to openly discuss their understanding of other water-related topics of interest. This process led to the identification of some key attitudinal differences amongst respondents relating to the natural environment generally and willingness to carry risks. More specifically, the willingness of some individuals to acquiesce to the current restriction regime seemed to be partly influenced by what risks

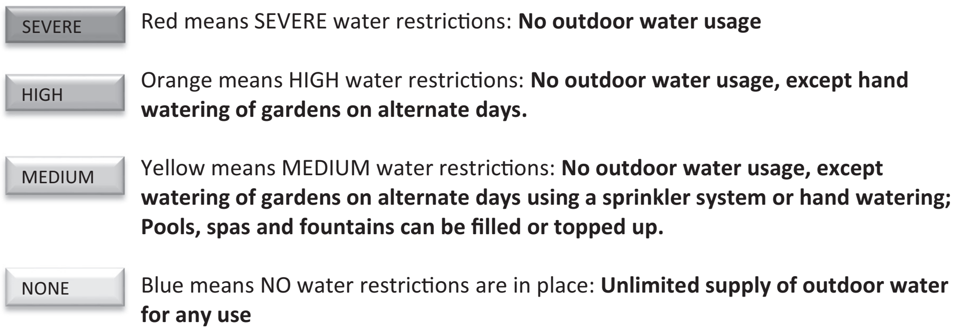

FIGURE 1 High-security water key. The different options for enhanced security are illustrated using different coloured bars. The colour of the bar represents the severity of the water restriction. When restrictions are imposed, the minimum period of restriction is 20 days.

were considered acceptable and there was also evidence that individuals related water use and environmental concerns.

The focus sessions also pointed to four attributes for the choice experiment. First, a per annum cost where the payment vehicle would be an additional annual charge on the customer's water bill seemed appropriate. The levels for this attribute were also tested in the focus sessions. Second, a meta-attribute was selected to capture the level of water security. Adapting the format developed by Cooper et al. (2018), water security was described in two ways, namely the probability that a supply constraint would occur and the severity of any constraint.[1] Thus, the attribute captured severity and the probability of an interruption to water access. This was done using coloured bars (e.g. red for most severe; blue for no restrictions) where the portion of each bar showed the probability of a restriction regime being imposed. The implications for water-using behaviour are summarised in Figure 1 (e.g. severe = no outdoor water use). Another main element of security pertains to the duration over which supply might be constrained. This was made explicit in the choice experiment and set at a minimum of 20 days but did not form part of the attributes in the experiment[2] (see Figure 1).

The status quo was described as follows: 20% chance of no restrictions, 40% chance of 'medium', 20% chance of 'high' and 20% chance of 'severe' restrictions. The constraints that related to each of these descriptors were also made clear (see Figure 2). By including 'no restrictions' as a level for the high-security water attribute, this imposes constraints on the design inasmuch as the probabilities assigned to each level must sum to 1. The probabilities for the status quo were developed based on historical data regarding water restrictions in the sample cities over the previous 10 years (e.g. YVW, 2012). In the higher security water contracts, the probabilities of facing a constraint were reallocated, while maintaining that they sum to 100%. For instance, if the probability of severe restrictions was reduced from 20% to zero, then the sum of the other three categories (i.e. no restrictions, medium and high restriction) was collectively increased by 20%.

Third, a 'green' water attribute was included where respondents were given the opportunity to contribute to better environmental outcomes in waterways. Here, it was specified that the water retailer would secure conservation covenants on behalf of its customers. These investments would reinstate and maintain native wetlands, add to river flows to

[1]It has become common in Australian cities to have restriction 'levels' during times of water shortage. Higher level restrictions are related to more stringent controls—like insistence on hand watering of gardens then escalating to a ban on all outdoor watering.

[2]Part of the rationale for this approach rests in the method by which restrictions are introduced and relaxed. In both cities, restrictions during winter and autumn are largely redundant as there is generally less demand for outside watering as days tend to be shorter, cooler and wetter. Thus, the maximum effective water restriction period is around 6 months.

	Option 1: Current Situation	Option 2
High Security Water	20% chance of SEVERE 20% chance of HIGH 40% chance of MEDIUM 20% chance of NONE	'Households in your city will not go on SEVERE' 40% chance of HIGH 40% chance of MEDIUM 20% chance of NONE
Green Water	NO	NO
Community Water	NO	NO
Additional Fee ($)	$0	$100
WHICH OPTION WOULD YOU CHOOSE?	❑	❑

FIGURE 2 Example choice set.

benefit indigenous species and protect native plants and wildlife throughout the state. This attribute was not constrained by the water security level for potable supplies used in the experiment. The logic for this is twofold. First, many native wetlands and native plants and wildlife in Australia are not located in regions that compete directly for urban supplies in these cities. Nonetheless, and as noted earlier, many households have a psychological link between their own water consumption patterns and the status of distant environments. Second, both cities in this study have the option to activate and expand desalination and reclaimed water schemes, which can be operated to shore up potable water security independently of achieving environmental gains.

Finally, a 'community' water attribute was incorporated where respondents were given the opportunity to support payments towards maintaining sporting ovals and common playgrounds in the event of a drought.[3] Essentially, buying into this attribute meant that all sporting ovals and common playgrounds that required watering in their city would not 'brown' during a drought—rather, they would be maintained for use. Again, this attribute was not constrained by the potable security options offered to the respondents. The survey instrument

[3]For clarity, participants from Melbourne were informed that the so-called 'Parks' charges that appear on existing bills did not cover the requirement to maintain local community assets of this form.

TABLE 1 Attributes and levels used in the choice sets.

Attribute	Descriptor	Status quo	Levels
High-security water	Frequency and severity of water restrictions	20% chance of none 40% chance of medium 20% chance of high 20% chance of severe	20%, 40%, 60%, 80%, 100% none 0%, 40%, 60%, 80% medium 0%, 20%, 40% high 0%, 20% severe
Green water	Improve environmental outcomes in respondents' state	No	Yes; No
Community water	Maintain all sporting ovals and common playgrounds in respondents' city	No	Yes; No
Additional fee ($)	$ per annum	$0 per annum	20; 50; 75; 100; 200; 600

was piloted, and this led to minor changes in the wording of some parts, but the overall structure remained unchanged.

The attributes and their levels are reported in Table 1, while a sample choice set is illustrated in Figure 2.

3.2 | Experimental design

An *efficient* design was employed in this study to generate the different choice sets. *Efficient* designs are developed to allow attribute levels to be assigned to the design in such a way that the elements of the variance–covariance (VC) matrix are expected to be minimised once data are accumulated. Here, we use an s-efficiency design criterion that minimises the sample size needed to identify the priors. The priors for the designs used in the full survey were derived from a MNL model estimated on the data generated from a pilot survey (see, e.g. Scarpa & Rose, 2008).

Describing water restrictions as probabilities raised a few challenges in the context of identifying an efficient design. Essentially, there are four risk attributes: the four levels of water restrictions, with the probabilities of facing each. However, those probability levels cannot be allowed to freely vary independently, as they must be non-negative, and sum to 100. Thus, a reduction in the risk of severe restrictions must result in an increase in the probability of some other outcome, which could be either no restrictions or possibly a higher probability of a lower-level restriction. Furthermore, we are interested in exploring the implications of offering respondents increased water security, not less.

This was dealt with using *Ngene*[4] by specifying a number of constraints on the levels and combinations of levels[5] (*Ngene* code available on request from the authors). For example, the levels for *Severe* were set to S(0, 20); that is, the probability of severe water restrictions was

[4]Ngene is an econometric software programme designed to generate stated choice experimental designs.

[5]In addition to the levels explained previously, it may be worth noting that the levels chosen for Medium were set to M (0, 40, 60, 80). Given that the baseline is 40%, and a requirement that the 'no restrictions' probability is at least 20%, increasing M to 60 or 80% requires either S or H (or both) to be reduced. Finally, the levels of probability of no water restrictions are set to N (20, 40, 60, 80, 100), with the further restriction that N = 100-M-H-S; that is, the probability levels across the four attributes assigned add to 100%. Once this set of restrictions is imposed, Ngene identified the efficient design, subject to these restrictions. A modified version of Ngene V1.1.1 was required to allow these restrictions to be imposed.

either maintained or reduced. The levels for *High* were set to H(0, 20, 40); that is, the level could be maintained at 20%, reduced to zero or possibly increased to 40%. However, the latter could only occur if S() = 0; that is, the contract had eliminated the probability of *Severe* restrictions, and assigned that risk to *High*. A full design, based on this specification, using dummy coding for the binary variables, and linear for the continuous variables was created, using 24 choice sets, blocked into four groups of six, optimising for S efficiency. The resulting design had an S estimate of 31 and a D error of 0.0026.

Because of the innovation in the design process, it was decided to include a second, smaller, more conservative design. The water security level consisted of either the status quo levels or 100% certainty of no water restrictions. Since this design had only three binary water attributes (no restrictions, Green and Community water) and cost, it was designed with 12 choice sets, blocked into four sets of three, with an S estimate of 72 and a D error of 0.0644. In the survey implementation, respondents saw six choice sets from the full design, followed by three from the smaller design.[6] Estimation can be undertaken using the pooled dataset, or the full-design dataset, or the small-design dataset.

3.3 | Survey administration

The data were collected in October 2012, after the Millennium drought but prior to the most recent drought episode. The survey consisted of four parts with the first containing questions regarding respondents' attitude towards several environment-related topics and their attitude towards taking risks. A 5-point Likert scale response format was used for all attitude items. The environmental questions were adapted from Thompson and Barton (1994), while those relating to risk were adapted from Weber et al. (2002). The environmental factor comprised six items, and the risk factor was developed using 40 items. Those who score more highly on risk are more likely to undertake risky behaviour, and those who score higher on environmental attitudes have a more favourable attitude towards the environment. The full set of attitudinal questions appears in Appendix S1. It is possible that the use of attitudinal variables to explain choices falls foul of endogeneity: that there is a common underlying unobserved factor that influences both choices and responses to the choice questions (Mariel & Arata, 2022; Mariel & Meyerhoff, 2016): we return to this issue in the Results section. The choice experiment was presented in the second section of the survey, and questions pertaining to the respondents' socio-economic status were included in part three. The final section was used to probe respondents about their willingness to pay to avoid water restrictions using a contingent valuation question. The focus of the remainder of this paper is on the results and findings of the choice experiment, particularly those drawn from a scale-extended latent class model.

The main questionnaire was distributed by an online survey company (Pureprofile) via email to a sample of residents from the predefined study locations. The response rate for the questionnaire was 45%, and the data comprised 497 respondents. Quotas were set to ensure a balanced sample by city with a total of 248 respondents sampled in Melbourne, and the remaining 249 were from Sydney. The Australian Bureau of Statistics (ABS) 2011 Census data were used for comparisons across sociodemographic variables. Restricting respondents to those above 18 years of age necessarily skews age, but the median household income of the populations of Melbourne and Sydney is equivalent to the median household income category of the sample. The sample had a statistically higher representation of tertiary-educated respondents compared with that of the population, but this is not unexpected (see,

[6]This distinction was unperceivable to respondents, as the attributes were identical (in the second alternative, the water restriction risk levels would either be at the status quo levels or 100% no restrictions and 0% all others).

TABLE 2 Sociodemographics of the survey sample and comparison with ABS census 2011.

	Sample	Population Melbourne and Sydney[a]
Average age	42 years	36 years
Own their home or mortgage	63%	67%
Male	41%	49%
Completed a tertiary degree	51%	33%
Proportion with an outdoor pool or spa	14%	12%[b]
Median household income before tax	\$1000–\$1499 per week	\$1390 per week
Average household size	1–2 people	2.6 people

[a]*Source*: ABS Census data (2011).
[b]*Source*: Roy Morgan Survey (2018).

Fleming & Bowden, 2009). Details of the sample and population comparisons are reported in Table 2.

4 | MODEL SPECIFICATION: SCALE-EXTENDED LATENT CLASS MODEL

4.1 | Background

There are several methods to allow for individual heterogeneity in the analysis of discrete choice experiments. It is possible to introduce observed personal characteristics (gender and education) as determinants of the marginal utility of attributes (i.e. observed heterogeneity). Alternatively, it is possible to assume that marginal utilities follow some distribution(s) and model these as random parameters (i.e. unobserved heterogeneity; McFadden & Train, 2000), although there is a need to specify the form of the mixing distribution (e.g. normal, log-normal and uniform). In contrast, one can assume that there are a finite number of classes of people, each with different preferences, using a latent class model (Train, 2009, p. 135),[7] or a combination of both latent and random parameter distributions (Greene & Hensher, 2013; Thiene et al., 2018). Here, we consider only a latent class model (LCM).

In the standard 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:

$$P\left(y_{it}=j|\,c\right)=\frac{\exp\left(\lambda\beta_c X_{ijt}\right)}{\sum_{n=1}^{N}\exp\left(\lambda\beta_c X_{int}\right)} \tag{1}$$

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

$$\lambda^2=\frac{\pi^2}{6\sigma^2} \tag{2}$$

[7]It needs to be acknowledged that the standard implementation of the LCM may lead to a misrepresentation of preference class structure if one ignores the possibility that there is heterogeneity in the error variance as well (Magidson & Vermunt, 2007) and that it is not possible to differentiate certain types of correlation in preferences from heterogeneity in error variance (Hess & Train, 2017).

As the number of classes C increases, the distributional flexibility of the latent class framework increases (Hess & Train, 2017). Statistically, there will be limitations to the number of classes that can be reliably identified within a sample, but there are no distributional restrictions associated with random parameter models.

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:

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

The choice of C is typically an empirical issue. As per Hole (2008) and Nylund et al. (2007), several information criteria can be used to identify the appropriate number of classes. These include Bayesian Information Criteria (BIC), Akaike Information Criteria 3 (AIC3) and Consistent Akaike Information Criteria (CAIC). Irrespective of the number of classes, the class membership of 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 individual attributes.

It is typically not possible to identify both the scale parameter λ and the marginal utilities uniquely, meaning the estimates are effectively scaled marginal utility parameters. That is, the estimated parameters $\overline{\beta_{ck}} = \lambda\beta_{ck}$. If scale is homogeneous for individuals within a class, then the conventional approach of scale parameter normalisation is appropriate (a standard LCM allows for scale heterogeneity across classes: see Hess and Train (2017)). However, as noted by Louviere and Eagle (2006) and Magidson and Vermunt (2007), if there is heterogeneity in the scale term (or equivalently, in the error variance), then this may lead to a confounding in the estimation of class structure. For example, assume that the utility parameters β_{ck} are the same across all individuals, but there are two groups, those with a higher scale value and those with a lower scale value ($\lambda_+; \lambda_-$). Empirically, in a conventional LCM, the two groups would appear to represent two latent classes, as their scaled marginal utilities appear to be different (i.e. $\lambda_+\beta_c = \overline{\beta_{c+}} \neq \overline{\beta_{c-}} = \lambda_-\beta_c$). This confounding due to the scale factor can be addressed if one empirically allows there to be *scale* latent classes as well as *preference* latent classes. As noted by Hess and Train (2017), it is not possible to fully differentiate the cause of any heterogeneity in scale that may be identified: one would identify a significant 'scale' effect if there were homogeneous error terms and within-class correlation across preference parameters. We return to this issue below, but note that for convenience we refer to a 'scale' parameter when discussing the results.

The choice probability (1) is extended when considering scale classes to:

$$P\left(y_{it} = j \mid c, s\right) = \frac{\exp\left(\lambda_s \beta_c X_{ijt}\right)}{\sum_{n=1}^{N} \exp\left(\lambda_s \beta_c X_{ijt}\right)} \tag{4}$$

The implementation of scale-extended latent class model (SELCM) follows a similar pattern to conventional models with an additional layer: one now also selects a priori the number of scale latent classes to be considered and estimates scale class membership probabilities along with preference class membership probabilities. If we assume that scale class and preference class are independently distributed, then the distribution of high and low scale classes will be proportional across preference classes. Introducing correlation between scale and preference latent classes allows the possibility that, for example, high-scale respondents are (probabilistically) clustered within certain preference classes. The probability of class membership of both preference and scale class is modelled as a multinomial logit, and sociodemographic variables can, in principle, be included in both.

In the SELCM, there is an issue of identifying the appropriate number of scale classes, equivalent to the issue of identifying the number of preference classes. The modelling strategy adopted here is to identify the appropriate latent class structure by estimating combinations of scale—and preference—class numbers and inspecting the information criteria, including individual-specific covariates to explain preference class membership.

4.2 | Coding of variables

The qualitative nature of some of the nonprice attributes means that the potential of nonlinearity in the marginal utilities between levels needs to be considered. Generally, such nonlinear relationships are represented using one of two data structures, namely dummy coding and effects coding. Dummy coding employs a series of 0s and 1s to relate each attribute level of the original variable to the newly created columns. In this case, the 'green' and 'community' water attributes were dummy coded.

The attribute focussed on water security is a composite, being the assigned probability of four levels of water restrictions. These were coded using the probabilities in the design. The baseline (i.e. no water restrictions) was omitted due to the probabilities summing to 100.

Two attitudinal covariates (attitudes to the environment and attitudes to risk—in both cases factor scores—had the mean set at zero with a standard deviation of 1) and four sociodemographic variables (age, income, gender and education) were used to explain class membership.[8]

The pooled dataset (from both full-design questions and small-design questions) was analysed in LatentGold Choice 6.0, using the Syntax module to estimate the SELCM outlined previously.

5 | RESULTS

5.1 | Determining the number of classes

The number of latent classes, C, must be determined empirically. In this case, two criteria were used to assist in determining the size of C, namely BIC and CAIC (Nylund et al., 2007; AIC measures failed to identify an optimal class structure in any model). It is recommended that these criteria are a guide only to determine the size of C as definitive rules for this purpose do not exist, so judgement and simplicity play a part in the final selection for the size of C (Scarpa & Thiene, 2005; Swait, 1994).

Inspection of the response to the questions, and in particular the proportion of respondents who selected the status quo option in all cases implied an *a prior* expectation that there may be a group within the sample who were either employing a heuristic in making choices or may have noncompensatory preferences. Therefore, all specifications initially assumed that the class structure would include a class where choices were random (all parameters constrained to be zero) and a class where only the alternative specific constant (ASC) effect was included (to accommodate a group who only considered the status quo option) and then a variable number (from 1 to 5) of unconstrained preference classes. Each

[8]Sociodemographic variables were found to be nonsignificant in explaining class membership, but a reviewer suggested that this null result was still of interest, and they should be retained. Class structure was identified for models both with and without the insignificant variables and led to the same result: see the Appendix S1.

of these seven models was estimated assuming 1 or 2 scale classes, and the information criteria results appear in the Appendix S2.[9]

Our results suggest that a two-scale class specification outperforms the single-scale class and that the favoured preference structure is for two additional unrestricted classes, along with the two restricted preference classes.[10] The implied sizes of classes in the preferred model suggest a small percentage (6%) who made choices at random and a large proportion who always selected the status quo (38%). We did not have unreasonably small percentages in the remaining classes (17% and 39%), and the implied preferences seemed plausible.

It is possible to impose a constraint such that the sample proportions of the scale classes are exactly replicated across all preference classes, or it is possible to allow for different preference classes to be made up of differing proportions of the scale classes. The latter is achieved by allowing for covariance/association relationships between the scale and preference classes. This extension is accepted based on a Wald test and implies that those with higher error variance are not distributed proportionality across preference classes. The implications for this for the distribution of class membership are discussed below.

5.2 | Model results

It is important to note that although in the section that follows we discuss blocks of results in sequence, the SELCM estimates the parameters to explain choices simultaneously: those of the utility function(s), the scale parameters, probability of scale and preference class membership as well as covariance terms between the two latent class types.

Table 3 reports the estimated results for the preferred model, a 4-preference and 2-scale-class model. The first section of the table (utility function: estimates) reports the parameters and significance of attributes in each of the four preference classes relative to the base levels. Both Classes 3 and 4 show a lack of concern around medium restrictions but are averse to high and severe restrictions. Class 3 has a preference for the provision of green water, while Class 4 does not. Neither value the community water attribute. Discussion of the relative weight of preferences is reserved until discussion of the willingness to pay values.

The second section of Table 3 (latent class membership: estimates) reports the parameters from a MNL model of preference class membership. Identification is achieved by imposing a constraint, such that the sum of parameters across all classes equals zero. Both environmental values (*envpred*) and risk aversion (*risk*) significantly explain some preference class membership. As noted previously, it is possible that the attitude variables are endogenous with the choices made; that is, potentially there is a common unobservable factor influencing both class membership and level of the attitudes. We think this is unlikely in the case of the risk variable, as the attitude variable is derived from a set of high-level perceptions about lifestyle risk. However, it is possible that this problem arises in the case of the environmental attitude. We explored the approach proposed by Mariel and Arata (2022) to test and correct for this but could not identify any suitable instruments to use in modelling the environmental attitude. We

[9]A reviewer suggested that the final structure arrived at may be influenced by the assumption of the two restricted classes at the start of the process and suggested we use a structure that goes from a general, unrestricted specification and then test whether some of the preference classes could be restricted. When we followed this process, we came to the same conclusion on the class structure: see the Appendix S1.

[10]Hess and Train (2017) suggest that it is unsurprising that a 2-scale class structure is preferred as it offers greater distributional flexibility as it effectively has 2xC classes and that a model with 2xC preference classes alone would provide greater flexibility. The fact that the single scale class model with seven preference classes is rejected relative to both the five preference class model, and the 2-scale 4-preference class model suggests that this extra flexibility is not required to represent the preference structure in the current case: whether it is due to a strong correlation structure across preference parameters, or variation in error variance; the SELCM provides a parsimonious representation of heterogeneity.

TABLE 3 Estimates for a 2-scale, 4-preference latent class model, with correlation between scale and preference class membership. Classes 1 and 2 restricted to be a random and an ASC class.

	Class 1		Class 2		Class 3		Class 4	
	coeff	**se**	**coeff**	**se**	**coeff**	**se**	**coeff**	**se**
Utility function: estimates								
cost	0	--	0	--	−0.197***	0.0745	−0.0612**	0.0267
med.res	0	--	0	--	−0.0064	0.0341	0.011	0.0362
high.res	0	--	0	--	−0.1648***	0.062	−0.3752*	0.1957
severe.res	0	--	0	--	−0.3472**	0.1629	−0.6782**	0.3372
green	0	--	0	--	3.7463**	1.7983	6.3239	3.9498
community	0	--	0	--	2.5956	1.8523	0.8384	2.0369
sq.asc	0	--	5.1341***	0.6351	−1.4215	1.058	−5.3447**	2.5478
Latent class membership: estimates								
Constant	−3.3621	6.1181	2.3899	2.0422	0.5921	2.0837	0.3801	2.1536
Risk	1.7814	1.1955	−0.753*	0.4154	−0.7290*	0.4117	−0.2995	0.4131
Envpred	−2.3827	2.0895	0.26	0.7072	0.9297	0.7076	1.19*	0.6977
Income	−0.0038**	0.0018	0.0011*	0.0006	0.0016**	0.0006	0.0011*	0.0006
Age	0.0715	0.0926	−0.0197	0.0313	−0.0229	0.032	−0.0289	0.0323
Male	−3.686	2.4356	1.2908	0.8235	1.2291	0.8349	1.1661	0.8424
Tertiary edu	0.6127	1.5189	−0.4458	0.5075	0.0152	0.5373	−0.1821	0.5769
Latent class membership: marginal effects								
	Class 1		**Class 2**		**Class 3**		**Class 4**	
risk	0.0419***	0.0083	−0.0552*	0.0297	−0.0355	0.0322	0.0489**	0.0231
envpred	−0.0507**	0.0204	−0.1218***	0.0266	0.0913***	0.0265	0.0812***	0.0212
Income	−0.001***	0.0000	−0.0000	0.0001	0.0001**	0.0001	−0.0000	0.0000
Age	0.0016	0.0012	0.0001	0.0022	−0.0005	0.0024	−0.0012	0.0018
Male	−0.084***	0.0237	0.0633	0.0518	0.0216	0.0553	−0.0009	0.0422
Tertiary edu	0.0150	0.0339	−0.0896	0.0523	0.0694	0.0543	0.0051	0.0443

(Continues)

TABLE 3 (Continued)

	Class 1		Class 2		Class 3		Class 4	
	coeff	**se**	**coeff**	**se**	**coeff**	**se**	**coeff**	**se**
Covariances between scale class and preference class (Joint Wald test: *p*-value = 0.0029)								
	coeff	**se**						
scale class 2 <–> preference class 1	−0.2337	3.0045						
scale class 2 <–> preference class 2	−1.9005*	1.0491						
scale class 2 <–> preference class 3	0.8744	1.0357						
scale class 2 <–> preference class 4	1.2598	1.0523						
Scale estimates								
	Scale class 1		**Scale class 2**					
	coeff	**se**	**coeff**	**se**				
Log-scale parameter	0	--	−2.3511	0.3809				
Class membership	0	--	0.2337	1.0133				
Estimated probability of class membership								
	Class 1	**Class 2**	**Class 3**	**Class 4**	**Total**			
Scale class 1	0.03	0.32	0.03	0.10	0.48			
Scale class 2	0.03	0.06	0.14	0.29	0.52			
Total	0.06	0.38	0.17	0.39				

Note: *, **, *** indicate *p*-values less than 0.1, 0.05 and 0.01, respectively. -- indicates constrained coefficient.

therefore note that there may be a bias in the parameter estimates associated with the class membership model.

Given class membership is modelled as a multinomial logit, it is well known that the native parameters may indicate neither the sign nor the significance of the marginal effects of these variables on the probability of class membership (see, Greene, 2008). We therefore also report marginal effects, where these represent the estimated change in the probability of class membership for a one-standard-deviation change in the *envpred* and *risk* variable. In the case of sociodemographic variables, marginal effects are expressed using unit changes, although it should be noted that the inclusion of the sociodemographic variables in the class membership model is not supported by Wald tests (p-values of 0.07, 0.81, 0.48 and 0.37 for income, age, gender and education, respectively).

Stronger levels of environmental values (*envpred*) tend to increase class membership of Classes 3 and 4 (where green water is valued positively) and reduce membership of Classes 1 and 2 (the random and ASC-only classes). Those who score more highly on *risk* (i.e. are more likely to undertake risky behaviour) are less likely to be in the class that only considers the status quo and more likely to be in the class that selects at random. Put differently, Class 1 is more risk-averse and inclined to select the status quo and Class 2 is more risk-seeking and makes less systematic selections in the choice experiment.

In Section 5 of Table 3 (scale estimates), the estimated 'scale' parameter λ for the two latent scale classes is reported. For identification, the value for Scale Class 1 is fixed at 1, while the estimate for Scale Class 2 is 0.061. If one takes an error variance interpretation of these results, it suggests that Scale Class 2 has a much higher variance in the random component of utility, although as Hess and Train (2017) note, it is not possible to differentiate the contribution of scale heterogeneity and positive correlation in preferences to this estimate.

The final block reports the posterior means of the probability of class membership across the sample, by scale and preference class. A relatively small group (6%) are in the random selection class, but 38% are in the ASC-only class. As one might expect, the latter is dominated by Scale Class 1, that is these respondents have a comparatively high level of consistency in choices, which indicates the value of allowing the correlation across the class structure. Approximately 17% and 39% of the sample are in Classes 3 and 4, respectively.

Table 4 reports estimates of willingness to pay for changes in the levels of the attribute compared with defined base levels (e.g. if the probability of a water restriction is reduced by 1%, the probability of 'no restriction' is increased equivalently). For example, Class 3 customers are willing to pay $1.76 to reduce the probability of *severe* water restrictions by 1%. In contrast, Class 4 customers are willing to pay $11.08 to achieve the same reduction in the risk of *severe* water restrictions being imposed. We also report values for the green and community attributes, even though the latter is not statistically significant. Note that these values are only available for Classes 3 and 4, given the preference structure of Classes 1 and 2. We

TABLE 4 WTP ($/year) for a 1% reduction in the probability of a water restriction of that level being imposed (and a 1% increase in the probability of no restriction) and WTP for a contract that specifies Green and Community water provision, by class.

	Class 3		Class 4	
	WTP	SE	WTP	SE
Medium	−0.03	0.17	0.18	0.58
High	0.84	0.16	6.13	1.22
Severe	1.76	0.25	11.08	1.70
Green water	19.02	4.15	103.27	41.78
Community water	13.18	6.02	13.69	31.08

offer the following generic labels to describe the four classes: Class 1—'Conservatives'; Class 2—'Indiscriminates'; Class 3—'Price sensitive Progressives'; and Class 4—'Progressives'.

6 | DISCUSSION

In the introductory section, we noted that economic regulators are increasingly encouraging water utilities to explore options that can better serve their customers, and this has partly stemmed from the universal nature of demand restrictions previously imposed during droughts. Earlier studies have shown that customers are generally willing to see the surety of water supplies improved, especially during severe drought, but issues of customer heterogeneity and the size of different customer segments have been relatively unexplored. The size of different segments and their differing appetite for change will be an important consideration for any water utility; after all, the utility must consider the transaction costs of developing and offering different 'products' to its customers and whether uptake by customers justifies the cost.

Positive preferences for a reduction in the probability of experiencing *High* and *Severe* water restrictions are apparent for individuals belonging to both Classes 3 and 4. Building on these estimates, we can identify various scenarios regarding respondents' willingness to pay to reduce the probability of facing *High* and *Severe* water restrictions to zero. For example, the willingness to pay estimates suggests that individuals in Class 3 are willing to pay approximately $35.20 to remove the 20% probability of experiencing *Severe* water restrictions, such that they face no water restrictions of that form. Class 4 individuals are willing to pay approximately $221.60 to achieve the same outcome. Class 3 would pay around $52 to remove both *Severe* and *High* restrictions, while Class 4 would pay almost $350 to remove the two more stringent restrictions.

In addition, it is also possible to estimate trade-offs that respondents in each class will make by shifting the risk of facing more severe restrictions to less onerous regimes. For instance, individuals in Class 4 are willing to pay approximately $99.00 to move a 20% probability of confronting the consequences of *Severe* water restrictions and modifying these such that they equate to *High* water restrictions. Class 3 customers are willing to pay substantially less (approximately $18.40) to achieve an equivalent outcome.

In some respects, these results are consistent with earlier studies that show that customers are generally tolerant of low-level restrictions on their water-using behaviours but are willing to forego significant sums to avert more severe constraints. Hensher et al. (2006) probably offer the most useful insights for comparison, albeit based on a different context and modelling approach. Hensher et al. (2006) ultimately disaggregate their data into water restrictions 'that matter' and those that 'do not matter', with the latter broadly equivalent to the *Medium* stage of restrictions used in our analysis. *Medium* restrictions were not significant for any category of customers in our case, including the two classes we have described as Progressives.

A key difference between Hensher et al. (2006) and this study stems, in part, from the different modelling approaches employed. A standard binary logit model was used by Hensher et al. (2006), which did not allow for the differentiation of classes. This raises interesting questions about how to apply the willingness to pay estimates, which in Hensher et al. (2006) are expressed as the mean for all households. Specifically, they find that 'customers need to be compensated by $227 on average (95% of $239) to accept an increase in the frequency of restrictions that matter from once every 20 years to once every year' (p. 62). In comparison, this study finds that progressive customers will pay around $350 to avoid 'restrictions that matter' while price-sensitive progressive customers would pay around $50 to avoid restrictions. In addition, there are sizeable classes of customers (indiscriminates and conservatives) who are not willing to pay to avoid restrictions. The additional insights offered by employing the scale-extended latent class choice model in this case highlight both the practical and political challenges of developing more customer-nuanced water services.

Hensher et al. (2006) also included an attribute relating to the amenity of parklands, not dissimilar to the *Community Water* attribute employed here. As with the earlier study, respondents showed no significant willingness to pay for this attribute in this instance.

Respondents in Class 3 are also willing to pay for enhanced environmental outcomes through sponsoring 'green' water. Respondents in Class 3 are willing to pay approximately $19.02 per annum to contribute to better environmental outcomes in their state. The fact that this attribute potentially relates to waterways at a significant distance to the respondent is consistent with other studies (e.g. Windle & Rolfe, 2005), which have shown that city dwellers often hold substantial nonuse values for environmental assets.

Clearly, there are substantial differences between Classes 3 and 4, although both have similar preferences for the attributes. Classes 3 and 4 hold similar preferences around reducing water restrictions, but Class 3 is much more price sensitive. As noted earlier, Classes 3 and 4 comprise around 17% and 40% of the sample and translated to the population; this represents a significant number of households in the study sites.

Set against these groups is a class of respondents who generally opt for the status quo, and this constitutes over a third of respondents. Again, translated across the population of urban water users in Sydney and Melbourne, this represents a significant number of households. This group is also defined by having less positive attitudes to the environment and being more risk-averse than those in Classes 3 and 4. Arguably, the risk aversion evident in this group plays out in a reluctance to change water restriction regimes, rather than accepting water supply contracts that give households fewer constraints on their water use.

Urban water utilities that ignore the preferences of 60% of their customers run the risk of criticism from regulators, who are increasing calling for alignment of water services with customer demand. However, there are also 38% of customers in this survey who have no desire to move away from the current regime and a further 6% with no clear interest in any option. How to reconcile the different amounts each segment is willing to pay will thus be problematic for utilities and modifying services will be a challenge, at least in the immediate term. The progressive roll-out of more sophisticated metering technology may offer promise. For instance, such devices could be configured to support tailored tariffs that are synchronised with household water-using behaviours and water availability. This would thus provide opportunities for customers to opt into alternative supply arrangements provided they are willing to bear additional costs.

Similarly, there is some evidence within these data that there would be a portion of customers who would opt to pay more on their water bills if they had an opportunity of securing 'green' outcomes, as currently occurs where customers pay a premium on their power bills to support renewable energy generation. This likely also points to the growing trend of customers perceiving water delivered for potable consumption as relating to environmental demands, even if the physical connectivity of water supplied for potable and environmental demands might differ. Catering for this sentiment could be achieved by allowing customers an opt-in where they make an additional payment to achieve environmental outcomes. Such an option would likely be taken up by a sizeable portion of existing customers and thus warrant the costs associated with its introduction.

In contrast, the willingness to pay for assigning water to community assets was not statistically significant, suggesting there is doubt that there would be a sizeable uptake if this was offered as part of a water service presented to households. This might well be explained by the fact that households already pay for community assets through council levies or similar charges and the significant public investments that were undertaken in both cities during the Millennium drought to make open spaces less exposed to constraints on potable water use during drought. It needs to also be acknowledged that some respondents may have been confounded by the prospect that the reliability of their own potable supplies would differ to that available for watering public spaces. The merits for urban utilities involving themselves in this domain are not supported by these data and require further analysis.

7 | CONCLUDING REMARKS

On the methodological front, the SELCM reported in this paper simultaneously groups individuals into relatively homogenous segments and explains the choice behaviour of members within those segments. This integrated modelling strategy provides an opportunity to combine different social, psychological and economic theories to help explain behaviour. Accordingly, the model allows a better understanding of urban water choice behaviour than that afforded by models, which assume homogeneity of preferences. In this case, the SELCM is used to identify the preferences of urban water users over attributes of a water supply contract, which could notionally be offered by their water utility. The preference class specification reveals differences in the strength of preference associated with water security and contributing towards better environmental outcomes. The scale class specification demonstrates that there are significant differences in the level of certainty in the random component of utility and that the distribution of this effect differs across preference classes. Accordingly, we have sought to offer some insight into how different groups of individuals are likely to respond where a differentiated urban water service or product is on offer.

Overall, the results support the view that there is an opportunity for water utilities to pursue approaches that allow customers more choice and to acknowledge that customers differ. Offering customers the option of a 'green' tariff would appear low risk for water utilities, especially if this is structured as an opt-in choice. Water service contracts that allow customers the opportunity to avoid the most onerous restrictions during drought would appeal to a majority of customers, at least on the basis of these results, and technological advances in the industry around metering might facilitate that. Nonetheless, history shows that community attitudes around 'sharing the burden of drought' can prove to be a powerful force, especially during an extended drought event. In that regard, nuancing water services to meet the needs of progressive customers is probably best attempted when dams are full.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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