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Adapting to Less Water: Household Willingness to Pay for Decentralised Water Systems in Urban Australia

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Abstract In South East Queensland (SEQ), extended periods of drought and unprecedented population growth have resulted in a water strategy reliant on permanent water conservation measures. As a result, there has been increasing emphasis on the installation of decentralised water systems at the household level, in particular, rainwater tanks and greywater systems to ease the water shortage stress. Results from a survey of 590 households in SEQ reveal that willingness to pay (WTP) for rainwater tanks and greywater systems range from $800 to $7,400 and from $1,700 to $14,100, respectively. When compared to the actual market price, WTP is substantially lower and subsidies will be required to encourage adoption. Nonetheless, a subsidy of $500 can lead to 100 % uptake of greywater diversion devices. Hence, the policy implication is that not all devices are preferred and subsidising greywater diversion devices would lead to the highest level of uptake with the least amount of subsidy spending.

Keywords Rainwater · Greywater · Rebate · Subsidy · Rainfall · Policy

1 Introduction

In the current context of climate change and rainfall uncertainties, water managers are faced with the increasing challenge of ensuring that potable water is available for basic needs. This challenge is exacerbated by rapid population increase and growing competition for water from other users that cannot be ignored, such as environmental water requirements. In order to combat water shortage problems, decentralised water systems (DWS) have been identified as viable options for meeting the growing demand for urban water. The adoption of DWS has the

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potential to increase household resilience to water shortages and help realise long-term economic benefits from reduced demand on scheme water.

Decentralised systems can take many forms (e.g. the use of rainwater, treated greywater, and groundwater), however, they are uniquely characterised as being located at, or close, to the point of use, such as within the property boundary of a house (Cook et al. 2009). Their purpose is to supplement scheme water supplies for non-potable applications such as gardening, toilet flushing, and laundry applications. Despite the imminent threat of severe water restrictions in South East Queensland (SEQ) during 2006 and 2007 and the financial and non-financial incentives offered by the Federal and Queensland government to encourage household adoption of DWS, only 50 % of the Queensland respondents in this study have voluntarily adopted the system.

While many scientists concentrate their efforts on understanding the social and economic implications of alternative *centralised* supply (e.g., desalination or recycled water), there is significantly less work looking at community reactions to DWS (see review by Mankad and Tapsuwan 2011). The small body of literature that does exist has argued that DWS are accepted because they assist in the conservation of potable water supply and reduce household scheme water expenditure (Marks et al. 2003). In the Australian Capital Territory, Ryan et al. (2009) found that adopters and non-adopters of greywater systems differ in their income, gender and attitude towards water recycling projects. However, they were not able to find any significant difference in demographics between users and non-users of rainwater. Nonetheless, these studies offer useful information that in addition to monetary factors, demographics and attitude also have an effect on adoption of decentralised water supplies.

Given that there has not been full adoption of DWS in SEQ, this study aims to investigate household preferences for DWS, the factors that have an impact on preferences and what subsidies might be required to enhance further adoption.

Although DWS are considered market goods, there is a lack of market data to reliably associate socio-economic and attitudinal information to DWS purchasing behaviour. Therefore in this study stated preference choice experiment (CE) is applied to determine whether households in SEQ are willing to pay for three different types of DWS: 1) bores and spear pumps, 2) rainwater tanks and 3) greywater systems. The amount of money that an individual is willing to pay is used to reflect his or her preference for one system over another.

2 The Stated Preference Model

In environmental valuation, one can ascertain how much an individual is willing to pay, on average, for a particular good or service (in this case DWS technology) by presenting him/her with a choice of product bundles at different prices. Although DWS are market goods, finding out how much people are willing to pay for future installations is still ascertaining preferences in the context of a hypothetical market. Given the current policy practice of intervening in markets and encouraging adoption through the use of consumer subsidies or mandated adoption, it is important to find out the gap between willingness to pay (WTP) and actual market price. Stated preference methods are frequently applied in the area of environmental economics due to their flexibility and ability to measure preferences in a hypothetical situation[1]

In this study, a CE is applied to determine whether households in SEQ are willing to pay for DWS. A CE survey is chosen primarily because it allows flexible alternatives and generates

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[1] See Bateman et al. (2002) for manual of stated preference methods.

considerable cost savings through the ability to value a number of options simultaneously (Gordon et al. 2001).

There are a number of ways to allow for individual heterogeneity in discrete choice experiments. The approach taken here is an extended latent class (LC) model. The advantage of the LC approach is that it allows for the identification of a number of classes of respondents who may hold quite different preferences. Within the constraint provided by the number of classes identified, there are no limits on the distribution of preferences, unlike the alternative approach of random parameter conditional logit models (Train 2009).

A conditional logit model assumes that the utility for individual i from an alternative j is given by:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

where ε_{ij} (distributed as an extreme value type I) and V_{ij} are the stochastic and deterministic elements of utility, respectively. In the linear case the latter can be extended to

$$V_{ij} = \beta_{ik} X_{ijk} \tag{2}$$

where X_{ijk} are the exogenous determinants of utility (potentially just the attributes, but possibly also attribute/individual characteristic interactions) and β_{ik} the marginal utilities.

If $y_i{=}j$ indicates that individual i selects option j from those available then (1) and (2) leads to the probability of individual i selecting option j from a set of N alternatives as:

$$P(y_i = j) = \frac{\exp(\lambda V_{ij})}{\sum_{n=1}^{N} \exp(\lambda V_{in})} \tag{3}$$

where λ is a scale parameter, defined by its relationship with the variance of the random term: $\lambda^2 = \frac{\pi^2}{6\sigma^2}$. It cannot be identified independently from the β's unless there is some other explicit model of how it may vary across the sample, and is usually normalised away.

Assuming that the parameters are homogenous across the population leads to a conventional conditional logit model. Allowing for heterogeneity in the population by assuming that these parameters are distributed across the population in some way (e.g. normal, triangular) leads to mixed logit models, where what is estimated are the parameters that define the distribution (mean and standard deviation). Although there have been a large number of applications of the mixed logit model as a mechanism to represent heterogeneity, they suffer from the need to specify the form of the mixing distribution.

An alternative specification is that of latent classes. Here the utility parameters are assumed to be constant across all individuals within a class, but may vary across classes:

$$P\left(y_i = j \middle| c\right) = \frac{\exp(\lambda \beta_{ck} X_{ijk})}{\sum_{n=1}^{N} \exp(\lambda \beta_{ck} X_{ink})} \tag{4}$$

i.e. the probability is conditioned on membership of class c. If there are a number of repeated choices made, then it is typically assumed that class membership does not vary across the tasks, i.e.

$$P\left(y_{it} = j \middle| c\right) = \frac{\exp(\lambda \beta_{ck} X_{ijkt})}{\sum_{n=1}^{N} \exp(\lambda \beta_{ck} X_{inkt})} \tag{5}$$

As the total number of classes C increases, the flexibility of the LC framework increases, and does not have the distributional restrictions associated with mixed logit models, but statistically there will be limitations to the number of classes that can be reliably identified within a sample: at the limit, as C approaches N, (the number of respondents), one is potentially estimating individual specific models, which the experimental design may not be able to support.

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:

$$P(\mathbf{y}_i) = \sum_{c=1}^{C} S_{ic} \prod_{t=1}^{T} P\left(y_{it} \middle| c\right) \tag{6}$$

The choice of C is typically an empirical issue, with a number of information criteria being proposed as means to identify the appropriate number of classes. Irrespective of the number of classes, the class membership of an individual is not imposed *ex ante*, but instead is treated probabilistically.

It should be noted that the scale parameter λ remains present in the LC specification, and that effectively one identifies classes based on differing scaled marginal utilites. If it is the case that scale is homogenous across individuals then the conventional approach of treating it as a nuisance parameter and normalising it away is appropriate. 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. This can be addressed if one empirically allows there to be *scale* latent classes as well as *utility* latent classes. These are called *scale extended latent class* models (Magidson and Vermunt 2007), and implementation of these models follows a similar pattern to convention LC models with an additional layer: one now also selects *a priori* the number of scale latent classes to be considered, and one estimates scale class membership probabilities along with utility class membership probabilities. Introducing correlation between scale and utility latent classes allows the possibility that scale class membership is not distributed proportionally across utility class membership.

The utility from choosing a particular option (here comprising a bundle of water technologies and a cost) is determined by the characteristics of the attributes, and individual specific characteristics are used to explain the probability of class membership. The assumed functional form for the utility (V_{ij}) for individual i of alternative j is specified as:

$$V_{ij} = \beta_s SQ_j + \sum \beta_T TECH_{Tj} + \alpha_{pr} PRICE_j \tag{7}$$

where:

SQ	is the status quo dummy variable (SQ =1 for Option IV, and SQ =0 for Options I, II and III)
$TECH_{Tj}$	is the presence of the DWS T (bore, rainwater tank, greywater system) in alternative j
$PRICE_j$	is the out-of-pocket expense (in \$)
β_s	is the coefficient of the SQ dummy variable
β_T	are the vector of marginal utilities, and
α_{pr}	is the coefficient on the price variable.

It is expected that WTP will increase with the size and sophistication of the DWS (i.e. households are willing to pay more for large rainwater tanks than medium size tanks).

Each choice situation consists of 3 options that comprise alternative bundles of DWS, plus a fourth option which is the status quo (SQ), or 'none-of-these' alternative. In the utility function, the SQ dummy, and the parameter associated with it, accounts for that element of utility associated with the 'no-change' option that cannot be accounted for by the attributes of the alternatives, and is usually attributed to an individual's innate preference for change.

The probability of class membership S_{ic} is modelled as a function of individual characteristics (Z_{ki}), using a multinomial logit model:

$$S_{ic} = \frac{\exp(\delta_{ck} Z_{ki})}{\sum_{j=1}^{C} \exp(\delta_{jz} Z_i)} \tag{8}$$

Identification is achieved by imposing that $\sum_{j=1}^{C} \delta_{jz} = 0$.

The coefficients estimated under the mixed logit model can be used to estimate the part-worth, or the maximum amount the respondent would be willing to pay to achieve a change in an attribute. The presence of the SQ effect in the model means that the amount an individual would be willing to pay for the introduction of a particular innovation is given by:

$$\text{Part–worth} = -\left(\frac{-\beta_S + \beta_T}{\alpha_{pr}}\right) \tag{10}$$

Published literature in economic valuation has argued the benefits of incorporating social psychological factors such as behaviour, attitudes, and beliefs into the economic utility function for predicting people's choices (e.g., Ben-Akiva et al. 1999; Spash et al. 2009). Protection Motivation (PM) Theory (Rogers 1975) is a cognitive mediation model which suggests threat is a key factor in understanding why people do or do not engage in adaptive behaviours. Relevant to this study is the adaptive behavior of installing DWS. According to the PM Theory, the concepts of adaptive and maladaptive coping have been shown to be important in understanding responses to environmental threats, such as earthquake preparedness (Mulilis and Lippa 1990), bush fire responses (Martin et al. 2009) and climate change (Grothmann and Patt 2005). As such, in this analysis, coping behaviour was included to explain population heterogeneity that is captured by class membership. It is hypothesised that positive coping behaviour would have a positive effect on WTP because the decision to install or use DWS is conceptualised as a product of the belief in one's ability to cope with water shortage threats.

As in many psychological constructs, coping behaviour cannot be measured directly. Therefore, a series of observable indicators were created. To analyse these constructs, factor analysis was used as a data reduction technique to generate a single composite variable for coping behaviour. The current study utilises the method specified in Eq. 9 to calculate the composite score for coping behaviour. The composite score is specified as

$$BE\widehat{H}AV_i = \omega_1 X_{1i} + \omega_2 X_{2i} + \ldots + \omega_n X_{ni} \tag{9}$$

where $BE\widehat{H}AV_i$ is the estimated composite score for a behavioural variable, ω_n are the factor score regression weights and X_{ni} are the observed score for each indicator.

3 Case Study

Nearly 100 % of households in SEQ rely on mains water as their source of potable water. Around 36 % of these households have rainwater tanks (ABS 2009). The benefit of rainwater tanks is that households are exempted from permanent water restrictions on outdoor water use.

There are also benefits of reduced water fees. At the societal level, the collective reduction of demand on scheme water delays the need for new dams or desalination plants.

To help combat present and anticipated water shortages, the Queensland government has stipulated that newly constructed homes in SEQ must have an on-site water device that provides up to 70kL of non-grid water to the home per year, thereby reducing mains water consumption by this amount (DIP 2010). The simplest way of achieving this is by installing a rainwater tank that is connected to laundry taps and toilet cistern. With older homes, DWS can be retrofitted. Homes that already have DWS are encouraged to install more. For an average Brisbane household of 2.5 people (DIP 2009), where per capita water consumption is approximately 150 l/day (QWC 2012), a 5,000 l tank holds approximately 4 weeks' worth of water. Estimates suggest that rainwater tanks of this size, if plumbed into laundry taps and toilet cistern, could reduce per capita consumption by 28–87 l per day (Beal et al. 2012). This amount of savings is only from one device. If multiple DWS are installed more water savings could be made.

4 Survey Design

4.1 Community Interview

Prior to the design of the CE survey, interviews with residents in SEQ with varying experiences with decentralised systems (i.e. have installed the system voluntarily, have installed the system because of the mandate, do not have the system) were conducted. Current owners of DWS were asked to describe their experiences with their system in terms of where the water was used, reasons for installing the system and how much they paid for the system. Others (non-users) were asked to explain why they did not have a system. The general consensus among users was that there was high acceptance for its use as both a potable (i.e., rainwater) and non-potable (e.g., greywater) source. In the case of non-users, the interviews helped to identify important barriers to adoption, which include cost and space availability on the property. Through the interviews, researchers were able to better understand users and non-users' perception of DWS and the acceptable use of this type of technology.

4.2 Online Survey Design

Findings from the interviews were used to guide the design of the CE survey. An online survey was conducted in June 2010 (prior to the extensive flooding in the region). The first section of the questionnaire introduced respondents to the study and its purpose. The second section consisted of questions related to water use, ownership of DWS and property characteristics (e.g. size of the property, roof area and proportion of garden size relative to property size). Roof area significantly influences the size of the tank because it limits the amount of rainwater that can be captured Ghisi 2010). Similarly, space availability on the property, as approximated by garden space relative to property size, also limit the size of the rainwater tank and where it can be placed. Space limitation may also influence households to install greywater systems over rainwater tanks because they are smaller.

The third section comprised drought coping behaviour questions. Statements measuring coping behaviours were based on Rogers (1983) PM model. In this context, use of the term 'behaviour' does not refer to observed behaviour, but rather a propensity to respond to threat in an adaptive (e.g., knowledge-seeking) or maladaptive (e.g., avoidant) manner. Respondents rated their level of agreement to statements describing methods of coping specific to water conservation and shortages. Concepts covered in the adaptive coping statements included intention to install DWS and active knowledge-seeking behaviour by home owners. Maladaptive coping statements included avoidance and learned helplessness behaviours, specific to water shortages in SEQ.

The fourth section consisted of the CE component. A statistical software package Ngene (version 1.0.2) was used to generate the orthogonal experimental design that was needed to construct the CE survey. An orthogonal design is a combination of alternatives which would allow the attribute levels to vary independent of one another (Bennett 1999). The design resulted in 48 choice sets that were then segmented into eight blocks of six choice sets each. A target number of $n=100$ respondents was set for each block of the survey. The final list of attributes and levels includes whether they have access to groundwater,[2] three sizes (<5000 l, 5,000–25,000 l, >25,000 l) for rainwater tank,[3] three types (Diversion device for outdoor use, Treatment devise for outdoor use, Treatment devise for outdoor/indoor use) for greywater systems,[4] and five levels for price, or out of pocket expense ($0, $1,500, $5,000, $10,000 and $15,000).

In the CE design, respondents were given the following statement as a guideline for water use:

> "*As a guide, on average an individual uses about 150 l of water per day for everything. If you have a 5,000 l rainwater tank as your only source of water, the tank would last you 30 days (with no rain refill).*"

In the choice sets, respondents were presented with a range of scenarios each consisting of three product bundles (Options I, II and III) that consisted of different sizes of rainwater tanks, different types of greywater systems and whether a bore was going to be installed or not (see Table 1). An option could contain only one type of technology or a combination of technologies. For example, an individual may prefer to have a small rainwater tank *and* a greywater diversion device over having just a single medium size rainwater tank. On the other hand, those who already have rainwater tanks may want a greywater system because they can use it when it does not rain. Therefore, this type of design is suited for those currently with existing decentralised technology and without. Respondents were told that choosing to purchase any of these bundles would help them become more self–reliant in the future, especially in face of future rainfall uncertainty and severe water restrictions. Option IV is identical in each CE. It represented a 'do-nothing' or 'stay with current system' situation and consequently has no out-of-pocket expense.

At the beginning of the CE survey, respondents were asked to consider their personal circumstances, including the intended use for the decentralised water (indoor/outdoor), the size of their roof, the space availability on their properties, and to keep in mind their budget constraints and make the choices as if they were *really* intending to buy. This was to make the decision as realistic as possible (i.e. to reduce hypothetical bias, a situation where stated WTP is different to actual WTP (Bateman et al. 2002).

In terms of price, respondents were informed that the price attached to each option was a one-off cost for purchase and installation of the system(s) after receiving government rebates. Hence, it was an out-of-pocket expense. We made the price attribute as realistic as possible by using actual market prices of the DWS, ranging from the cost of purchasing one device, to all three devices. After completing the choice sets, respondents were asked a debrief question to ascertain if they found the choice sets confusing. The final section comprised standard social demographic questions.

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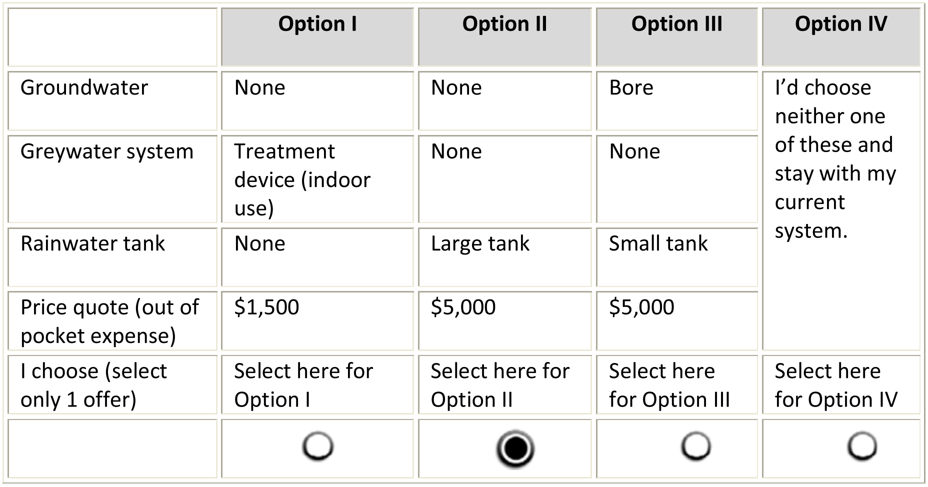
[2] BORE, dummy coded=1 if present, 0 otherwise

[3] STANK, MTANK and LTANK respectively, dummy coded 1 if present, 0 otherwise.

[4] GREYDD, GREYTO and GREYTI respectively, dummy coded =1 if present, 0 otherwise.

Table 1 Example of a choice set as seen by respondents via the online survey. Carefully consider the four options proposed below (Options I, II, III and IV). If only these four options were available for consideration, which would you prefer?. Please answer the following questions as if you were *really intending to purchase* the system and consider how much you can afford to pay



	Option I	**Option II**	**Option III**	**Option IV**
Groundwater	None	None	Bore	I'd choose neither one of these and stay with my current system.
Greywater system	Treatment device (indoor use)	None	None	
Rainwater tank	None	Large tank	Small tank	
Price quote (out of pocket expense)	$1,500	$5,000	$5,000	
I choose (select only 1 offer)	Select here for Option I	Select here for Option II	Select here for Option III	Select here for Option IV
	○	●	○	○

4.3 Participant Recruitment

Respondents were recruited through an online research panel from local government areas within SEQ; potential respondents were verified as SEQ residents through their self-reported postcodes. The advantage of employing an online research panel is that sample participants can be selected to ensure representativeness of SEQ residents based on the distribution of age, income, gender and postcode. SEQ residents included in this study were initially screened to ensure that they were home owners (or paying a mortgage) of a free-standing dwelling that was connected to mains water. This was to prevent people that did not engage in DWS purchase decisions (e.g. short-term renters) or people that were not reliant on mains water as their primary water source (e.g. rural property owners), as they may cloud results aimed at measuring homeowners' preferences for DWS ownership. Owners of mandated rainwater tanks were also excluded from the analysis as the focus of the earlier part of the study was on voluntary adoption.[5] Respondents initially received an invitation email to take part in the survey and after accepting the invitation, they were given a hyperlink to complete the survey. Current DWS owners and non-owners participated in the survey.

5 Results

5.1 Descriptive Statistics

Of 590 respondents in the study, 57.1 % were female. Approximately 62 % of respondents were aged under 60. While the proportion of males and females were comparable to the Australian

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[5] See Mankad et al. (2012) for socio-demographic factors affecting water use patterns of households with mandatory rainwater tanks in South East Queensland (SEQ).

Bureau of Statistics population data (ABS 2006), the current sample comprised a higher proportion of respondents over the age of 60. However, this skew was expected, given the need for respondents to be home owners. Therefore, these delimitations were not believed to be problematic. Over one-third of respondents (34.7 %) reported high school as their highest educational attainment and a similar percentage (35 %) had tertiary qualifications. Approximately two-thirds of respondents (62 %) reported a gross annual household income below $90,000.

The average number of adults per household was 2.23 and most respondents (74 %) did not have children younger than 18 years of age living at home. The average property size was 1,990 sqm (standard deviation of 7,069 sqm). The average roof size was 250 sqm (standard deviation of 163 sqm). The average proportion of garden area was 47 % (standard deviation of 18 %).

When asked whether they owned a rainwater tank, under half of respondents (44.6 %) said *yes,*[6] 54.4 % said *no*, and 1 % were unsure. Around 39 % of respondents reported using greywater at home but mainly through manual bucketing, or connecting a flexible hose to their washing machines. Only 5 % of respondents had a plumbed greywater system installed.[7] A very small proportion of respondents (5 %) owned two types of technology and one participant owned all three types of technology.

5.2 Coping Behaviour

Respondents were asked to rate how much they agreed or disagreed with five statements relating to their adaptive coping behaviour to water shortages. A confirmatory factor analysis in MPlus (Muthén and Muthén 2010) suggested that only four of the statements, held together well in a congeneric measurement model of adaptive coping behaviour (Cronbachs alpha for scale=0.67). The four statements were *"I will be better able to reduce water shortages if I read or hear more about alternative water options", "I am planning on using less town/mains water in the future", "I am planning on only using greywater or rainwater to maintain my garden in the near future"*, and *"I am considering installing an additional alternative water source on my property (e.g. larger rainwater tank) so that I am less reliant on towns/mains water"*. The mean value for adaptive coping behaviour was 3.20 (standard deviation of 0.67). On the other hand, respondents were asked to rate, on a five-point scale, how much they agreed or disagreed with six statements relating to maladaptive behaviours relating to minimising the impact of water shortages. Respondents with high maladaptive scores tended to dismiss, or denied water shortages problems in SEQ. They also did not think they could make a difference to water shortage problems facing SEQ. Participants with high maladaptive scores were, therefore, less likely to adopt DWS. Confirmatory factor analysis suggested that four maladaptive factors, fit well as a single congeneric measurement model of maladaptive coping behaviour (Cronbachs alpha for scale=0.65). The four statements were "*I try not to think about the possibility of water shortages", "What I do on my property wont have any real impact on water shortages in SEQ", "I have stopped listening to people going on about water shortages because I am tired of hearing about the topic"*, and *"Water shortages are inevitable, there is nothing we can do about it"*. The mean value for maladaptive behaviour was 2.59 (standard deviation of 0.66).[8]

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[6] Percentage of respondents who owned small, medium and large rainwater tanks were 16.67 %, 25.93 % and 2.02 %, respectively.

[7] Percentage of respondents who owned greywater diversion devices for outdoor, greywater treatment systems for outdoor, and greywater treatment systems for indoor and outdoor were 1.52 %, 3.54 % and 0.17 %, respectively.

[8] The mean scores, factor loadings and factor score coefficients for the adaptive and maladaptive coping statements will be provided upon request.

Responses to statements measuring adaptive and maladaptive behaviours were then combined to form a single coping behaviour score (ADAPT). Composite scores on maladaptive coping were subtracted from the composite adaptive coping scores, as per Rogers (1983), method. A total behavioural coping score ranged from −3.63 to 4.05 with a mean of 0.61 (standard deviation of 1.09). A low coping behaviour score refers to individuals who would not engage in specific behaviours to minimise the impact of water shortages, as such are less likely to adopt DWS, while a high coping behaviour score refers to individuals who are more likely to adopt DWS.

5.3 Extended Latent Class Results

A search was performed to find the appropriate LC structure across two dimensions: the number of preference classes, ranging from 1 to 9, and the number of scale classes, ranging from 1 to 3.[9] Selection of the best model from the 27 available was based on standard information criteria. BIC and CAIC measures suggest that a 4 utility class, 2 scale class model is preferred.[10] Only income and ADAPT were found to be significant in explaining utility class membership probabilities.

We now turn to a detailed examination of the estimation results for the 4 utility class/2 scale class model, in Table 2. Although we will be discussing separate elements of the results individually, it is important to remember that all elements are estimated jointly.

The first block reports the estimated utility parameters for each of the 4 classes, with the associated *p* value. Classes 2 and 3 show high levels of attendance to all attributes, the principle differences being in the significant negative coefficient associated with the SQ dummy in Class 3 (implying this group is looking favourably on change), and much lower sensitivity to cost. The full impact of the latter will be revealed in the discussion of the part-worths associated with each attribute, which will come later. Class 1 value most attributes in the system, but have a strong negative response to the presence of a bore. Class 4 represents a group that only value greywater systems.

The second block reports the parameters of the multinomial logit model to explain class membership. These are initially reported as raw parameters, but interpretation of these in terms of impact on probability of class membership is not straightforward, and so the marginal effects (δ(prob)/δX) are reported below class membership in Table 2 (see Green, 2009). Changes in level of the adaption and income variables lead to changes in the probabilities of being a member of classes 3 and 4, with an increase in both of these attributes leading to increased membership of class 3, and reduced probability of membership of class 4.

The third block of data relates to scale heterogeneity. The value for scale class 1 is fixed to unity for identification, while that for scale class 2 is estimated freely. A strongly significant value of 7.41 means that for scale class 2 the variance of the error term (which is inversely related to scale) is much lower i.e. scale class 2 are much more certain in the choices they make. CONFUSE, which =1 if they reported they were confused with the choice tasks, is significant in explaining scale class membership. Those who report themselves to be confused were less likely to be a member of the class with the lower error variance.[11] The covariance

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[9] All estimation is with LatentGold Choice, 4.5.

[10] A table with log likelihood values and information criteria for each preference class range and scale can be provided upon request.

[11] 17 % of respondents reported there were confused with the choice sets.

Table 2 Results from a 2 scale- 4 utility latent class model

	Class 1	P value	Class 2	P value	Class 3	P value	Class 4	P value
Utility functions								
SQ	0.0268	0.85	0.0642	0.12	−0.1935	0.031	1.0535	0.098
BORE	−2.7267	4.9E-08	0.1063	0.0083	0.0433	0.11	−0.5666	0.11
STANK	0.4012	0.04	0.1741	0.0023	0.0985	0.012	0.2148	0.45
MTANK	0.4306	0.079	0.1757	0.0018	0.1461	0.003	0.4475	0.17
LTANK	0.3064	0.023	0.07	0.059	0.0707	0.051	0.0605	0.79
GREYDD	0.9796	0.00074	0.1413	0.017	0.1875	0.0031	1.5353	0.0018
GREYTO	0.659	0.0018	0.296	0.00074	0.2361	0.0012	1.4512	0.0025
GREYTI	1.202	0.00014	0.3295	0.00047	0.2807	0.00098	0.9823	0.025
PRICE	−0.1355	7.8E-06	−0.0846	0.00057	−0.0199	0.00085	−0.5472	6.5E-07
Class membership								
CONSTANT	−0.6609	0.081	0.5626	0.1	−1.1414	0.047	1.2397	2.5E-06
ADAPT	−0.0106	0.94	−0.0035	0.97	0.3877	0.0013	−0.3736	0.00018
INCOME	0.0467	0.2	−0.0139	0.61	0.0499	0.084	−0.0826	0.00088
Marginal impacts								
	Class 1	Sig.	Class2	Sig.	Class 3	Sig.	Class 4	Sig.
ADAPT	0.009		0.024		0.076	***	−0.109	***
INCOME	0.009	*	0.002		0.012	**	−0.023	***
Scale			Scale class1		P value		Scale class2	P value
				1			7.4111	1.30E-04
Scale class membership								
CONSTANT					−0.4428	1.20E-02	0.4428	1.20E-02
CONFUSE					0.4002	2.80E-02	−0.4002	2.80E-02
Covariance between scale and utility classes								
					sClass1	P value		
Utility Class 1					0.6752	0.0049		
Utility Class 2					−0.2542	0.34		
Utility Class 3					−0.8835	0.095		
Utility Class 4					0.4626	0.020		
Predicted probability of utility class membership								
sClass		Class 1	Class 2		Class 3		Class 4	Total
1		0.0866	0.0741		0.0123		0.2015	0.3745
2		0.0473	0.2592		0.1517		0.1673	0.6255
Total		0.1339	0.3333		0.164		0.3688	1

***,**,* indicate significance at 1,5 and 10 % respectively

terms report the degree of association between utility class membership and scale class membership. A Wald test for whether these covariances are jointly significantly different from zero is accepted at a probability level of 0.0002, for 3 degrees of freedom.

It is possible to generate a probability of class membership, across both utility and scale latent classes (see final block of Table 2). Although some 62 % of the sample is in the low variance (scale class 2) group, they are not distributed across the utility classes evenly: proportionally they are much more focussed in utility classes 2 and 3, who are the classes

Table 3 Part-worths ($’000) per unit change

	Class 1	Class2	Class 3	Class 4
Status quo	0.2	0.8	−9.7**	1.9
Bores	−20.1***	1.3***	2.2	−1.0
Small rainwater tank	3.0**	2.1***	5.0**	0.4
Medium rainwater tank	3.2*	2.1***	7.4***	0.8
Large rainwater tank	2.3**	0.8*	3.6*	0.1
Greywater diversion device	7.2***	1.7**	9.4***	2.8***
Greywater treatment device (outdoor)	4.9**	3.5***	11.9***	2.6***
Greywater treatment device (indoor/ outdoor)	8.9***	3.9***	14.1***	1.8**

***,**,* indicate significance at 1,5 and 10 % respectively

that appear to have attended to majority of the attributes, while class 4 has a much higher proportion of those who have a high variance.

5.4 Willingness to Pay

Although one can consider differences in marginal utilities in Table 2, one is still confounded by potential differences in scale across utility classes. Evaluating part-worths, or marginal WTP, for attributes is more informative. Table 3 reports WTP for attributes by each class, evaluated using the Krinsky-Robb simulation technique. Our central measure of WTP is the median value of 10,000 draws of the WTP estimate. Note that WTP for greywater systems are positive and significant across all classes, as compared to rainwater tanks where class 4 appears to have a non-significant WTP for rainwater tanks of any size. In summary, WTP for rainwater tanks and greywater systems range from $800 to $7,400 and from $1,700 to $14,100, respectively. The maximum WTP for bores is $1,300 and only class 2 shows a positive and significant WTP. Class 1 shows a significant negative WTP for bores which indicates that this group would have to be compensated, in addition to receiving full subsidy for the cost of bore purchasing and installation, to have bores in their homes.

Table 4 Proportion of adopters and expected subsidy required to increase adoption ($’000)

Technology	Market price	Proportion of sample that will buy with no ($) subsidy	Additional proportion of sample that will buy with ($) subsidy			
			+17 %	+13 %	+33 %	+37 %
Bores	1.7	0 %			0.4	
Small rainwater tank	3.75	17 %		0.75	1.65	
Medium rainwater tank	4.75	17 %		1.55	2.65	
Large rainwater tank	5.75	0 %	2.15	3.45	4.95	
Greywater diversion device	2.2	67 %			0.5*	
Greywater treatment device (outdoor)	7	17 %		2.1	3.5	4.4*
Greywater treatment device (indoor/ outdoor)	10	17 %		1.1	6.1	8.2*

*100 % Adoption is achieved

It is convenient to split the WTP estimates into two components: that associated with the SQ effect, and that due to technology attributes. A positive SQ effect implies a preference for no change, and change will only be undertaken if the net benefit of the technology bundle has a positive value which exceeds the SQ value. On the other hand, a negative SQ effect implies a preference for change, and although the WTP associated with a technology bundle may be negative, adoption may occur if that is less (in absolute terms) than the SQ effect. The decomposition is particularly important as the SQ impact holds irrespective of the number of technologies within the option i.e. it represents a “fixed” effect, independent of the type or number of technologies being evaluated. In this analysis, the SQ effect is negative and significant only for class 3, indicating that these group of people are averse to doing nothing.

6 Discussion and Conclusion

In comparison to the current market price, the stated WTP levels indicate that adoption level will be low (17 % or less) for most types of systems, except for greywater diversion device, where 67 % of the sample show a higher WTP than the market price. Hence, greywater devices appear to be the most preferred decentralised water system.

Table 4 presents the market price for each technology and the level of subsidy required in order to increase the level of adoption for each type of system. In this table, subsidies were not estimated for non-significant (or zero) WTP values, where the subsidy would have to be equivalent to the price of the technology, nor for negative WTPs. The figures in Table 4 indicate that 100 % adoption of greywater diversion devices can be achieved if a $500 subsidy is offered, while a maxium subsidy of $4,400 and $8,200 would be required to achieve 100 % adoption of greywater treatment devices for outdoor and for indoor/outdoor, respectively.

The WTP for rainwater tanks and bores reveal that a full price subsidy is required to achieve 100 % adoption. Subsidies of $1,650, $2,650 and $4,950 for small, medium and large rainwater tanks, respectively, would increase the adoption level to 63 % of the sample. In order for the remaining 37 % of the sample to install rainwater tanks, the technology would have to be given out for free. As for bores, a $400 rebate will increase adoption from 0 % to 33 %. However, the remaining 67 % of the sample would have to be given bores for free.

The small preference for bores may stem from the fact that respondents were under the impression that bores are prohibitive in SEQ. For example, one respondent stated that “*A lot of the scenarios involved a bore which we are unable by Brisbane City council rules to put in*”, while another respondent commented that “*You can't sink bores in Brisbane*”. However, the fact is, in SEQ there are no regulations that prohibit households from obtaining a bore water license. In some areas, a license is not even required for domestic bores (DERM 2011). Sprinkler restrictions, which are strictly applied on scheme water users, are not applied on bore water users (QWC 2012). Hence, the lack of interest in bore installation may come from misinformed perceptions.

If the SEQ government decides to offer any type of subsidy to increase the adoption of DWS, subsidies for greywater diversion devices would be the best value for money as a rebate of $500 per installation could lead to 100 % adoption of the system.

In response to the current knowledge gap in the literature surrounding decentralised water technology uptake, this study reveals that households are able to overcome the emotional factors associated with treated wastewater, as demonstrated by their preferences for greywater systems over rainwater tanks and bores. However, the level of WTP reveals that only a small proportion of the sample is willing to pay more than the price of the technology. The rest of the sample, despite their positive attitude towards adopting DWS, is willing to pay less than the current market price, which rationalises why there are still many non-adopters in SEQ. The lack of interest may stem from the fact that respondents believe that water shortages are no longer an important issue due to current (high) dam levels in Southeast Queensland (Mankad et al. 2010).

The results may appear less encouraging but the analysis allows us to identify the size of the divergence between private values and private costs, and hence the financial incentives required to close the gap between these two values. This information is useful for policy decision making as it provides insights into which technology to subsidise first in order to achieve 100 % uptake and how much financial investment is required. It also is useful for water demand and supply balance planning because the reduction in per capita demand can be anticipated based on the level of subsidy given to adopt decentralised water technologies. An alternative to subsidies is to increase the volumetric price of water to reduce demand and speed the uptake of decentralised technology. However, price increases are not socially desirable as compared to subsidies as there are equity issues that come into play.

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