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Reclaimed Wastewater and the WTP to Avoid Summer Water Restrictions: Incorporating Endogenous Free-Riding Beliefs

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Abstract

Climate change may cause more frequent seasonal water shortages. Water-scarce countries already use reclaimed household wastewater for subsequent uses that do not require potable water. Views on the degree of acceptability of reusing wastewater and a distrust of one's water provider may deter countries like Canada and the United Kingdom from adopting these technologies. This paper reports on results from a 2009 Canadian Internet-based contingent valuation study. Two water management programs were presented: a program to reduce summer water use through water restrictions and a program to allow citizens to avoid summer water restrictions through the use of reclaimed household wastewater. The paper estimates the willingness-to-pay (WTP) for the second program and finds trust in the water utility, belief in future drought conditions, and age to be important factors, as is the belief that members of one's community will not voluntarily reduce water use by the required amount. The latter introduces a potential endogeneity bias in responses to discrete choice WTP questions. Joint estimation of the underlying WTP function with a model to explain a respondent's belief in community free riding is undertaken. The paper contributes to the literature on valuing the avoidance of water restrictions, elicitation of free riding beliefs, and the use of endogenous regressors in discrete choice models.

Keywords: water shortages, reclaimed wastewater, WTP, free riding beliefs, endogeneity in discrete choice models

JEL Classification: Q25, Q51, Q53

Introduction

Along with a number of other countries, Canada has historically enjoyed relatively abundant supplies of good quality water overall. However, climate change may change this fortunate situation. It is predicted to increase the variability of available water supplies, thereby making supply shortages and water quality concerns into more frequent and widespread occurrences. Indeed, Canada has already experienced more frequent summer droughts and many communities have resorted to the use of summer water restrictions. Regions of the world where water supplies are scarce have already adopted a number of approaches to use their valuable water resources more efficiently through water reclamation, reuse and recycling. Some areas in Australia and the United States have found that consumers view such intensification of use with fear and this has led to rejection of some water reusing projects (Marks, 2004). Other areas have been successful in implementing reuse technologies (California Department of Water Services, 2003; City of San Diego Water Department, 2006).

This paper reports on the results from a contingent valuation study on reclaimed wastewater done in 2009 with a representative sample of over 1,300 Canadians. The survey presents a scenario describing two water management programs for a community: a program of summer outdoor water restrictions and a program that avoids these restrictions through the use of reclaimed household wastewater for toilet flushing. Respondents answer two discrete choice referendum questions to elicit the willingness-to-pay to avoid reductions of either 10% or 30% in summer water use through water supplies supplemented with reclaimed wastewater to be used for toilet flushing.

Since the success of the first program ultimately depends upon community member participation that may be costly to monitor, free riding is possible. In order to account for the possible impact that belief in free riding might have upon WTP for the second program, respondents are asked to indicate whether they believe members of their community will free ride. While these responses help to explain WTP responses for the water reclamation program, they introduce a potential endogeneity bias. In order to accommodate this, a respondent's belief in free riding is estimated jointly with the responses to the dichotomous choice WTP questions using a recursive simultaneous equations Mixed-Process approach (Roodman, 2009). WTP estimates with and without the endogenous free riding assumption are presented to identify the magnitude of the potential bias.

The paper contributes to the non-market valuation literature by incorporating endogeneity of potential regressors into the discrete choice estimation framework and in providing estimates of WTP for reclaimed wastewater that can be used in a cost-benefit analysis of the impacts of climate change upon water supplies.

Background

The rest of the world looks enviously at Canada's apparently abundant water resources: approximately 7% of renewable fresh water and less than one percent of the world's population. However, pressure on this resource is growing. Over the period 1972 to 1996, the annual rate of water withdrawals increased by almost 90% - from 24 billion cubic metres to 45 billion cubic meters. At the same time, however, the population increased by only 33.6% (Environment Canada, 2011). This combination has helped to contribute to Canada's position as the second highest per capita user of water in the world

(Boyd, 2001). Such an unabated thirst for water, particularly from a population increasingly concentrated in a small number of urban centres, means that water utilities need to consider more carefully how to use available supplies in a more sustainable manner. Over the last few years, they have become more aware of the challenges facing them, challenges that are likely to be exacerbated by the anticipation of increasing variability of precipitation arising from climate change (Canada. NRTEE, 2010).

Around the world countries that are less water rich than Canada have adopted a number of measures to either discourage water use and/or augment water supplies in innovative ways. Australia, in particular, has been at the forefront of these efforts. Water conservation efforts are practiced in most major centres and, as of 2008, 75% of Australians live in communities that employ some form of mandatory water use restrictions, particularly with respect to summer outdoor uses (Grafton and Ward, 2008). In addition, augmentation of water supplies is pursued in a number of ways. Collection and reuse of reclaimed wastewater to supply the needs of a number of subsequent water uses –particularly, irrigation, urban and residential landscape uses, car washing, and toilet flushing - is seen as being capable of providing a reliable alternative to traditional water supplies. Across the world the percentage of reclaimed wastewater being used as a percentage of total wastewater varies greatly with dry countries like Israel having larger percentages (Erickson, 2004, Asano, 2007). Dolničar and Saunders (2006) say the relevant number for Australia is about 4 %, largely for agricultural irrigation and landscape watering purposes, although some is used for toilet flushing. Amongst these is the high profile use of recycled water for toilet flushing in what was the 2000 Summer Olympic Athlete's Village.

In contrast to a number of new residential initiatives in Australia, there are only a handful of examples in Canada, e.g., agricultural irrigation in Alberta and British Columbia and a few demonstration projects in selected urban settings (Exall, 2004). In the last year, however, a Working Group on Domestic Reclaimed Water of the Federal-Provincial-Territorial Committee on Health and the Environment have developed guidelines as a result of growing interest in water conservation in Canada (Health Canada, 2010). While the focus of these guidelines is the protection of public health, the document notes that factors contributing to an interest in reclaimed water use in Canada include… "seasonal water shortages and droughts (potentially exacerbated by climate change", as well as, "overburdened traditional water sources" (p. 3). Canada, with its apparent vast water supplies, is therefore not immune to scarcity and would do well to consider alternative means of providing water services. In this regard, the goals of this paper are two-fold. The first is to identify the degree of public acceptance of supplementing existing water supplies with reclaimed wastewater. The second is to calculate the WTP to avoid summer water restrictions that have become increasingly common across Canada by supplementing traditional water supplies with reclaimed wastewater that is suitable for toilet flushing.

Literature Review

Over the last decade, the general public has become more aware of how predicted changes in temperature due to climate change may reduce the reliability of water supplies and necessitate reductions in the amount of water used in urban settings. The message of increasing water scarcity has sharpened due to repeated experience with summer water restrictions in many countries (Olmstead, 2010). In the face of this new reality, Kallis et al (2010) report that Californians say that they are willing to take shorter showers, flush the toilet less, stop washing their cars, reduce garden watering and even stop lawn watering.

A number of different non-market valuation techniques have been used to put an estimate on the value to households of being able to either reduce the severity of or avoid entirely restrictions on outdoor water use. The first set of papers employ stated preference approaches on respondents from the United States, the United Kingdom or Australia. Green et al (1993) use an iterative bidding CV format in a face-to-face setting with residents of the United Kingdom and find the mean WTP per household per year to reduce the risk of supply restrictions is between £11 and £41per year (1992 £). On the other hand, Garrod et al (2000) use contingent ranking and find that households in Southern England are not willing to accept an improved water supply at the cost of environmental degradation. In one of the first studies of American subjects, Howe and Smith (1994) use an open-ended CV question format to determine the willingness to avoid restrictions to outdoor water use that amount to usage of only three hours every third day during summer months in relatively dry southern cities in Colorado. Around half of the respondents say that they are simply not willing to accept a decrease in water supply. However, of those willing to face this possibility, the authors find the range of willingness to accept values between $4.53 and $13.99 per month (1994 $US). Koss and Khawaja (2001) use both dichotomous choice CV mail and telephone formats and find similar average WTP values - between $11.67 and 16.92 per month - for California residents depending upon the severity of the water restrictions (1993 US$). Griffin and Mjelde (2000) use a mail survey with both a single dichotomous choice CV question, as well as, an open-ended WTP question. Respondents in their American sample are WTP a one-time amount of $25.34 (2000 US $) in order to avoid a 10% shortfall over the "next 14 summer days and WTP $8.47 more on the monthly water bill in order to obtain a longer-term expansion in water system reliability that will allow them to avoid future water restrictions of up to 20% of demand. Interestingly, greater experience with previous water shortfalls tends to lower the WTP. The authors argue that experience encourages water-saving coping behaviours and purchases of water-saving devices, thereby lowering values that consumers assign to shortfalls. This may be a factor in the findings from Australia noted below where WTP values are generally lower than those already discussed.

Moving from the Northern Hemisphere and regions with relatively abundant water supplies to the Southern Hemisphere and regions that are generally water scarce, one of the first non-market studies to value the WTP to avoid water restrictions is Blamey et al (1999). Employing face-to-face conjoint analysis interviews in Australia and evaluating a number of different scenarios, their results suggest first that the average household is WTP $10 (1997 $AU) per year to prevent a 10% reduction in personal water use. Second, they are WTP $18 (1997 $AU) per year to achieve some improvement in Canberra's urban public appearance, however, not to achieve entirely green public spaces. Hensher et al (2006) use choice experiments with respondents located in Canberra. They find that the population is not willing to pay to avoid restrictions that are less severe than those defined by stage 3. On average, however, the WTP per household to move from a Stage 3 situation (Stage 3 restrictions continuously every day all year every year) to a situation of absolutely no restrictions is $239 per year (2005 $AU). This is equivalent to 31.26% of the average annual water bill.[2] However, they also find that respondents are generally not WTP to avoid low-level water restrictions. While the WTP value may seem large, at least half of all water consumed by the residential sector in Australian capital cities is used on private outdoor areas (Brennan et al 2007). Tapsuwan et al (2007) use an internet-based choice experiments survey format to determine the WTP to increase the number of days on which sprinklers can be used. The sample of Perth respondents is WTP approximately a 22% increase in household water bills which is equivalent to $57 per household per year (2007 $AU). In exchange, they expect to be able to increase their use of sprinklers from one day a week to three days a week. Cooper and Crase (2009) use a payment card approach to obtain the annual WTP to avoid water restrictions completely throughout the year in a number of cities in Australia. Their estimates range between -$4.86 and $107.05 (2009 $AU) for the entire sample. Respondents who believe that the actions of their household will not influence the overall water situation are more WTP to avoid water restrictions. In addition, a variable indicating a lower intention to comply with water restrictions is associated with a greater WTP to avoid such restrictions. Finally, respondents from water-poor cities have lower WTP. In a similar fashion to Griffin and Mjelde (2000) they argue that citizens of these cities have invested in less water-using durables.

A second way to obtain values associated with the WTP to avoid water restrictions is to infer the welfare costs associated with water restrictions from behaviour undertaken in related markets. Russell et al (1970) look at observable out-of-pocket costs to water users and finds them to be $5 to $13 per capita (1970 $US) in New England. However, for the study, subjects are assumed to have homogeneous preferences for the greenness of their lawns. Using a household production function model that accounts for time costs of less efficient hand-watering, Brennan et al (2007) find the welfare costs of sprinkler bans in Perth to fall between \$2.55 and \$80.29 (2007 \$AU) per year depending upon incomes and subject's preferences for "greenness". Hatton MacDonald et al (2010) use hedonic pricing to infer from property values the implicit value residents place upon proximity to private green spaces and public green spaces. In theory, such values can be associated with welfare gains associated with the avoidance of water restrictions. They do not find evidence of such price differentials for Adelaide.

A few articles link the WTP to avoid water restrictions with willingness to pay for changes to water supply options that implicitly remove water restrictions. One alternative source of reliable water supply is reclaimed wastewater. Reclaimed wastewater provides a number of environmental social benefits, including a reduction in the introduction of a potentially damaging effluent stream into sensitive ecosystems and these benefits may be valuable to households (Anderson, 2003; Scarpa et al 2007). However, reclaimed wastewater also provides private benefits to consumers in the form of a reliable supply of water in drought-stricken areas or during summer periods when rainfall is lower and demands for outdoor water uses are higher. Gordon et al (2001) use face-to-face choice experiments with residents of the Australian Capital Territory (ACT) to obtain an implicit WTP of \$47 (1999 \$AU) for the provision of recycled water for outdoor use. However, they find that this WTP falls to -\$55 for the situation of recycled water for all uses. The authors interpret this as a WTP to avoid drinking recycled water. Tapsuwan et al (2007) also use a choice experiments with subjects from Perth to obtain household benefits associated with the avoidance of water restrictions via the use of new sources of water supply, including the injection of treated recycled wastewater into underground aquifers. Householders are WTP a premium of 62% more on their water bills for the aquifer injection option rather than endure severe water restrictions. An important finding that mirrors work elsewhere on the relative acceptability of reclaimed wastewater is that male respondents are more in favour of the option than female respondents; however, they find no other significant socio-demographic factors (Leviston et al 2006).

While the previous work suggests that some consumers may embrace the opportunity to use reclaimed wastewater as a means of avoiding summer water restrictions, others may be unwilling to accept its use. Health concerns and other factors pertaining to personal views on the use of reclaimed wastewater may make these individuals unwilling to view it as an acceptable alternative form of water supply that would obviate the need for summer water restrictions. A review of the literature on experience with and attitudes towards the use of recycled and/or reclaimed wastewater provides a better understanding of a number of the motivations that may underlie stated preference survey responses.

The literature in this area emphasizes that sources of personal objections to the use of reclaimed wastewater arise from environmental, economic, and health concerns, as well as lack of trust in the ability of the water utility to manage risks and the nature of the secondary use to which the reclaimed water is to be put (Bruvold, 1988; Hamilton, 1994, Hurlimann and McKay, 2004, Menegaki et al, 2007). Bruvold (1981) notes, in particular, that the general public is likely to be willing to entertain moderate contact uses of reclaimed water but are unlikely to accept it for subsequent potable water use. This is possibly due to the so-called “yuck” factor identified by Po et al (2003). It may be that such an attitude is softening, particularly in light of growing water shortfalls in Australia. Marks et al (2008) report on recent baseline data on acceptance of recycled water by Australians. For example, 23% of respondents report having experience with some form of public or municipal water recycling, thereby removing the unfamiliarity aspect. Toilet flushing is the most acceptable form of subsequent use of reclaimed wastewater (95 % of households are in favour).

Survey and Data

Survey data from a CV question format are used in this paper to explore the willingness of Canadians to use reclaimed wastewater for toilet flushing as a means of avoiding summer water restrictions. Focus groups were used to clarify issues and question wording and the full questionnaire was tested online prior to final survey implementation. This took place during the months of April to June 2009. Members of the Ipsos-Reid Internet-enabled panel - currently numbering over 125,000 individuals - were randomly recruited for the survey via email. Ipsos-Reid offered financial incentives to their panel members; however, respondents were not told the subject of the survey prior to receiving any questions. In order to ensure saliency, it was decided to include only respondents on a city or municipal water system directly responsible for paying for their utilities. Upon accessing the survey respondents were screened to include only those individuals on municipal water systems since the payment vehicle in the survey is the household water bill. A complete set of data was compiled for 1135 respondents across Canada with about 3000 email invitations originally sent out. The sample was both nationally and geographically representative. The most recent Census of Canada was conducted in 2006. For Canada, as a whole, mean household income is reported as

$70,000, the median age is 48 and the population as a whole in Canada is 50 % female. Table 1 shows some summary statistics for selected variables from the respondents in the dataset.

In addition to collecting information about the socio-economic demography of respondents such as marital status, income, age, education and number of children, the first set of questions were used to determine respondents' experiences with water shortages and their views about the potential impacts of climate change upon future droughts. When asked how many times the community they lived in had imposed water restrictions in the previous 5 years: 22% of the respondents answered zero, 7.8% answered once, 11.3% replied twice, 11% replied three times, 5.1% replied four times and 41.9% said that they had experienced water restrictions each year for the last five years. On the issue of whether they believed the scientist's predictions that summer droughts were likely to become more frequent and severe in Canada: 63.2% replied yes; 14.3% replied no; and 22.6% said that they did not know. These responses suggest that, in spite of the apparent bounty of water in Canada, Canadians are aware of potential water shortages and that the valuation scenario presenting "water reclamation as a substitute for water restrictions" is believable and within their level of understanding.

The next section of the survey presented respondents with information about reclaimed water and possible subsequent uses. Respondents were first asked whether they had previously heard about reclaimed water (over 56% said yes) and then asked a series of 5 point Likert-scale questions designed to identify the degree of acceptance of a number of subsequent uses of reclaimed wastewater. The mean values for seven possible subsequent uses ranging from watering golf courses to tap water are presented in Table 2.

Canadians are no different from residents of other countries. They are willing to consider using reclaimed water for purposes that entail little contact but there is very little willingness to consider its use in augmenting tap water supplies (Gordon et al 2001, Marks et al 2008). For the purposes of the subsequent discussion about the WTP results from the CV question that described reclaimed water as being used for toilet flushing, it is interesting to note that 59% strongly agree with this use and a further 21 % somewhat agree. In total, there is about an 80 % acceptance rate which is quite a bit lower than that found by Marks et al (2008) for Australian residents. The difference may be attributable to the greater experience with reclaimed water in Australia than in Canada (Exall, 2004; Asano, 2007). Alternatively, awareness of the relative scarcity of traditional water supplies in Australia may be the more salient rationale in these observed cross-country differences.

Prior to being asked the valuation questions, respondents were presented with an information screen entitled "Investing in Your Community's Future Water Supply". This screen told respondents that they would be asked to vote on management programs pertaining to their community's water supply. Respondents were then given a description of a future of more frequent water shortages for communities that could be handled in one of two ways, identified as Option A and Option B. Option A was described as a water reduction program that would require all community members to reduce overall summer water use. The program described restrictions on when private lawns could be watered (every second day only in the early morning and late in the evening), outdoor car washing limitations, and when public spaces would be watered (once a week), and noted that business and firms found in noncompliance would be subject to financial penalties.[3]

Option B was described as a water supply augmentation program. It described a program of sewer infrastructure and upgrading that would allow the piping of reclaimed wastewater back to homes through a separate system to be used only for toilet flushing. Respondents were told that the reclaimed water would not look or smell any differently from regular tap water. The augmented supply was described as being sufficient to obviate the need for any summer water restrictions. After describing these options respondents were asked whether they believed that members of their community would reduce their summer water use by the amount described in Option A as being the required water reduction. Fifty-one % of respondents said they thought other members of their community would reduce their water use by less than the required amount. Respondents were also asked if they themselves would reduce their summer water use by the required amount and only 24 % said they themselves would reduce their water use by less than needed.

A double-bounded CV format was used to elicit preferences pertaining to Option B. Respondents were asked to pay additional monthly amounts on their household water bills. These amounts ranged between $1 and $60 (Can $). Prior to these questions, respondents were reminded of their budget constraints and of the relationship between Options A and B. In order to examine scale issues related to the magnitude of good being valued, a split sample was used in which approximately half of the respondents were told that the summer water restrictions would require a 10 % reduction in water use and the other half were told that it would require a 30% reduction. In each case, respondents were told that reclaimed wastewater supply augmentation would be sufficient to prevent these reductions being used.

The survey concluded with a series of debriefing questions designed to obtain more information on respondent motivations. In particular, focus groups had identified distrust of water utilities' abilities to handle potential health risks of reclaimed water as a potential deterrent of being willing to accept augmented water supplies instead of water reductions. Two variables were used. The first was a 4-point Likert scale variable designed to identify whether respondents had any health concerns with respect to their current status quo tap water situation, with increasing values suggesting a greater expressed level of concern. Second, a new variable was constructed by adding together responses to three 5-point Likert scale questions designed to represent an increasing degree of distrust. The questions were "I do not trust my community water supplier to ensure water safety and quality", "I do not think that my community water supplier provides information that can be trusted", and "I do not trust my community water supplier to manage any risk that may be associated with using reclaimed water for toilet flushing". These variables were used with traditional socio-demographic ones like income, presence of young children in a household, age, and gender as possible shifters in a WTP function.

Econometric Model and Estimated WTP

The econometric model begins with equation (1) that describes respondent j's unobserved true willingness-to-pay (WTP^*_j) to avoid lawn watering restrictions by water supplies augmented by reclaimed wastewater. It is assumed that WTP^*_j depends upon a vector of explanatory variables (X_j). The error term is assumed to be normal with mean zero and standard deviation, σ.

$$WTP_j^* = X_j{}'\beta + \varepsilon_j \qquad (1)$$

In order to elicit the respondent's WTP, the researcher relies upon the respondent's responses to two dichotomous choice questions. Respondents are first asked whether they are willing to vote in favour of paying a specific additional amount on their monthly water bill to obtain the good described in the scenario. A positive response indicates that the WTP is at least as great as the first specified amount and triggers a second question: are they willing to vote in favour of an even greater amount? However, a negative response to the first question suggests that the WTP is less than the first specified amount and triggers a second question: are they willing to vote in favour of paying an even lower amount? As a result of these two sets of responses the researcher can classify each respondent into a payment interval: [Y_{jL} , Y_{jU}] where the lower bound value (L) is either negative infinity for the respondent who says no both times or the lowest payment presented and accepted (if a respondent's first no response is followed by a yes response). The upper bounds are defined in a similar way (either the highest payment requested and accepted (if they first say yes, followed by a no) or plus infinity (if they said yes both times). This means that the true WTP for some respondents will fall within an interval of real values while this interval will be left-censored for the respondents who said no twice and right-censored for the respondents who said yes twice. After collecting the interval information for each respondent, the contribution of respondent j to the likelihood function's value is represented either by an interval or else is right or left censored.

$$
\begin{aligned}
&\Pr(Y_{jL} \le WTP_j^* \le Y_{jU}) \\
&= \Pr(Y_{jL} \le X_j{}'\beta + \varepsilon_j \le Y_{jU}) \text{ for interval data} \\
&\text{or} \\
&= \Pr\,(X_j{}'\beta + \varepsilon_j \le Y_{jU}) \text{ for left - censored data} \\
&\text{or} \\
&= \Pr\,(Y_{jL} \le X_j{}'\beta + \varepsilon_j) \text{ for right - censored data}
\end{aligned}
\qquad (2)
$$

The log-likelihood function to be maximized is given in equation (3) for the sample of N respondents, where the subset LC are located in the left-censored interval, the subset RC are located in the right-censored interval and the subset I are located in the (uncensored) interval. Φ(.) is the standard normal cumulative probability density function. Implicitly, –(1/σ) is the coefficient on the payment requested, so this represents the scale factor used in valuation. As Cameron and James (1987) show the estimated coefficients from (3) can be used with equation (1) to obtain estimates of mean WTP.

$$
\begin{aligned}
LLF = &\sum_{j=LC} \log \Phi(\frac{Y_{jL} - X\beta}{\sigma}) + \sum_{j=RC} \log\left(1 - \Phi(\frac{Y_{jU} - X\beta}{\sigma})\right) \\
&+ \sum_{j=I} \log\left(\Phi(\frac{Y_{jU} - X\beta}{\sigma}) - \Phi(\frac{Y_{jL} - X\beta}{\sigma})\right)
\end{aligned}
\qquad (3)
$$

Equation (3) is estimated with STATA 11. Table 3 presents each regressor's coefficient scaled by –(1/σ); thus, each coefficient represents a marginal willingness to pay for a small change in that regressor, holding all else constant. As Table 3 shows respondents are very sensitive to the size of the payment (σ is significantly different from zero). Additional factors that reduce the probability of a respondent being WTP include: age, distrust in the ability of the water utility to manage health risks, and disagreement with the idea that reclaimed wastewater can be used for subsequent toilet flushing. On the other hand, respondents who say that they have previously heard of reclaimed water are much more likely to vote yes to the supply augmentation program that will allow them to avoid lawn watering restrictions.[4] Another positive and significant regressor in the yes vote decision is belief in scientists' predictions of future droughts. This has a marginal willingness to pay of $8.08.

Using sample means for explanatory variables, the estimated mean WTP from this Interval Censored model are $9.31 (estimated std. error of $1.084) per household per month for avoiding 30 % water restriction and $7.93 (estimated std. error of $1.095) for avoiding the 10% water restriction. Given the wide variety of survey formats, payment vehicles, and valuation scenarios discussed in the literature section, it is difficult to compare the WTP results from this survey with previous ones. Two points are worth mentioning. First, these values are similar to the ones obtained from American respondents but larger than the ones generally obtained from surveys using Australian respondents. This may be a reflection of Australian's longer-term experience with water shortages and subsequent adjustments in behaviour that make them less susceptible to further water restrictions.

While these WTP values for the sample, as a whole are interesting, an important issue is raised when one looks at the sign on and significance of the variable used to indicate that a respondent believes other members of her community are unlikely to reduce their water use by the required amount. Specifically, the estimated coefficient is positive and significantly different from zero. This says that respondents who believe others in their community will not comply with water restrictions are more likely to say yes to Option B (water augmentation program) and their marginal WTP is $6.52. Interestingly, this suggests that a respondent's belief in the free riding behaviour of others is likely to elicit a positive WTP. This seems somewhat contradictory to the traditional view of free riding; namely, that economic agents do not find it rational to voluntarily contribute to a public good from which they cannot be excluded (Olson, 1968). The question can be asked: why should they voluntarily contribute to a public good from which shirkers cannot be excluded? Perhaps, one solution is that the average member of the public responding to these surveys is not an economist. Maxwell and Ames (1981) report on a number of public goods experiments designed to verify the free rider hypothesis. They find that, while economics graduate students tend to contribute less to a public good than others, the majority of the subjects in their experiments voluntarily contribute substantial portions of their resources to the provision of a public good. The results from the current survey certainly support the Maxwell and Ames findings.

The finding that there is a greater probability of a respondent who believes her neighbours to be free riders to be WTP to avoid lawn watering restrictions through reclaimed water usage raises the interesting issue of possible endogeneity of regressors. That is, if some of the factors that determine a respondent's belief in the free-riding behaviour of others are correlated with some of the factors that determine her underlying WTP, then failure to account for such correlation may lead to inconsistent coefficient estimates.

In order to account for endogeneity a second model is estimated using the data from the survey by defining a recursive simultaneous multi-equation model that contains two equations. The first specifies the existence of an unobserved latent variable (Z^*_j) that describes a respondent's belief in other's free riding behaviour (equation (4)). Equation (4) is a probit model with Z_j=1 describing a situation where a respondent has answered affirmatively to the question that she believes members of her community will not reduce their watering by as much as required. The vector F contains variables that help explain why a respondent answers yes.

$$
\begin{aligned}
&Z_j^* = F_j{}'\alpha + e_j \\
&Z_j = 1 \quad \text{if } Z_j^* > 0; \quad 0 \text{ otherwise}
\end{aligned}
\tag{4}
$$

The second equation is the latent WTP* described in equation (1) above. However, now it is recognized that one of the explanatory variables included in the X vector of equation (1) is Z^*_j which may be endogenous. If ε_j and e_j are jointly normally distributed with zero mean and a diagonal covariance matrix, then the researcher does not need to be concerned about endogeneity. However, if the error terms are correlated, then the covariance matrix will have non-zero off-diagonal elements.

While the two equations are simultaneously estimated, it is assumed that they are governed by a recursive or multi-stage process. That is, the respondent's belief in free riding behaviour of others is a determinant of her true WTP, however, the converse is not true. Under this condition the two equations form a mixed process (probit equation and interval censored equation) that can be estimated simultaneously using the cmp program written for STATA (Roodman 2009). In addition to estimates of the coefficients in each equation, the results also provide an estimate of the correlation coefficient between the errors. The null hypothesis of exogeneity (zero correlation) can be tested.

Table 4 presents results from the Mixed-Process model. The top of the table shows the estimates of the probit model that explain a person's belief in the free riding behaviour of other members of her community. Two explanatory variables are used: age and one's own free riding behaviour expressed as a dummy variable with the value of 1 indicating that the person has said that she would not reduce her own water consumption by the required amount for Option A. This latter variable is positive and significantly different from zero. Following these estimates are the estimates for the censored interval regression using the same explanatory variables as earlier. A comparison of estimated coefficients in Tables 3 and 4 shows very little change in their values, suggesting that endogeneity is not present. This is confirmed by the insignificant correlation coefficient for the errors in the two regressions. However, its negative sign is consistent with the downwardly biased coefficient on free riding beliefs in the first model. If the correlation had been significant, then the estimated WTPs from the interval censored model that does not account for possible endogeneity effects would have been potentially biased. The estimated WTP from the Mixed Process Probit-Interval Censored Model for the 30 % water restriction case is \$9.26 (estimated std. error of \$4.34), which is slightly lower than the earlier WTP estimate. The WTP for the smaller water restriction is \$7.95 (estimated std. error of \$4.20), essentially unchanged from the earlier estimate. It may be that the impact of endogenous free riding beliefs on the decision to vote yes is sensitive to the size of the good being valued (in this case, the degree of water restrictions being requested).

Conclusions and Suggestions for Future Work

This paper has investigated the extent to which domestic water users in Canada are willing to pay in order to avoid summer outdoor water restrictions via the use of water supplies augmented with reclaimed wastewater that can be used for toilet flushing. After establishing that a majority of Canadians believe that climate change will have a negative impact upon future water supplies and that toilet flushing is one of the most acceptable subsequent uses for reclaimed wastewater, the paper reviews the literature to obtain previous estimates of the WTP to avoid lawn watering restrictions, as well as work on household perceptions of reclaimed wastewater.

Results from the first Canadian-based survey to examine the WTP to avoid lawn water restrictions amounting to a 30% reduction suggest that the average household is WTP around $9.26 (2009 $Can) per month on the household water bill. Since the average monthly bill is approximately $30 per month, this represents more than a 30 % increase. This value is similar to that found for American residents but larger than values obtained from a number of Australian studies. However, this is consistent with the finding that more water-stressed places have lower WTP to avoid lawn water restrictions because they have invested in water-saving devices and adjusted their behaviours (Griffin and Mjelde, 2000). This cannot be said about Canadians in general, however, since they still consume more water per capita than residents of all other countries (than the United States) and about half of this is used for outdoor purposes, largely lawn watering.

The paper also examined issues around free riding. In developing the CV question about WTP to avoid lawn-watering restrictions, it was recognized that the success of the program depends upon community member participation and this is costly to monitor, therefore, free riding is possible. Belief in free riding might have an impact upon how a respondent answers the WTP questions. In order to account for potential endogeneity of a regressor in a discrete choice model, a probit model is estimated jointly with the interval censored model explaining WTP responses using a recursive simultaneous equations approach developed by Roodman (2009) for STATA. While the estimated correlation coefficient for the errors in the two models is found to be negative, it is not significantly different from zero for the particular specification presented in the paper. However, other sources of endogeneity may be present and have a significant impact upon how respondents answer CV questions. Future work will examine whether self-reported perceived health risks from the use of reclaimed water plays a role in altering respondent behaviour and WTP.

Table 1: Socio-demographic characteristics of sample

Variable	Mean	Std. Dev	Minimum	Maximum
Male Dummy	0.55	0.49	0	1
Age	47.49	15.46	18	86
University Dummy	0.65	0.48	0	1
30% Good	0.50	0.50	0	1
Health Concern	1.41	0.74	1	4
Previous Water Restrictions Dummy	0.77	0.42	0	1
Believe Scientists Drought Predictions Dummy	0.63	0.48	0	1
Heard of Reclaimed Wastewater Dummy	0.56	0.50	0	1
Use of Reclaimed Water for Toilet Flushing	1.79	1.17	1	5
Respondent Believes Others Will Reduce Water Use By Less than Requested Dummy	0.51	0.50	0	1
Respondent Will Reduce Water Use by Less than Requested Dummy	0.24	0.42	0	1
Distrust	7.71	2.40	3	15
Households with Kids under 18 Dummy	0.33	0.47	0	1
Income ($1,000 2009 $CAN)	71.31	37.87	2.5	150

Table 2: Acceptability of reclaimed wastewater in possible subsequent uses

(% of sample respondents)

	Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Agree	Strongly Disagree
Toilet Flushing	59	21	9	5	6
Watering Vegetables in Garden	36	28	13	16	8
Watering Grass or Flowers in Garden	60	25	10	3	3
Agricultural Irrigation	50	25	10	11	5
Watering of Public Parks	61	24	8	4	2
Watering of Golf Courses	69	20	7	3	2
Tap Water	11	13	14	25	37

Table 3: Interval Censored Regression Results

Variable	Coefficient	Estimated Std. Error	p-value
Income ($1,000 2009 $CAN)	0.0222	0.0197	0.261
Male Dummy	-1.1418	1.4900	0.443
Age	-0.1222**	0.0509	0.016
University Dummy	-2.0588	1.5550	0.185
Previous Water Restrictions Dummy	2.0856	1.7680	0.238
Believe Scientists Drought Predictions Dummy	8.0777*	1.6048	0.000
Heard of Reclaimed Wastewater Dummy	4.0387*	1.5087	0.007
Do Not Agree with Use of Reclaimed Water for Toilet Flushing	-2.0818*	0.6626	0.002
Households with Kids under 18 Dummy	2.1566	1.6755	0.198
30% Good Dummy	1.3829	1.4936	0.354
Health Concern	0.0815	1.0756	0.940
Believe Others Will Reduce Water Use By Less than Requested Dummy	6.5170*	1.5200	0.000
Distrust	-1.0471*	0.3338	0.002
Constant	12.8315*	4.8640	0.008
σ (scale)	21.1147*	0.7696	0.000
LLF=-1414.6982			
LR χ^2 (13) = 112.11 (p=0.000)			

* significant at 1% level; ** significant at 5% level

Table 4: Mixed-Process Regression Results: Probit on Free-Riding Beliefs with Interval Censored Regression

Variable	Coefficient	Estimated Std. Error	p-value
Probit for Belief that others will reduce less			
Age	-0.0045	0.0025	0.078
Self Reduce By Less Dummy	1.3218*	0.1043	0.000
Constant	-0.0398	0.1282	0.756
Interval Censored Regression			
Income ($1,000 2009 $CAN)	0.0217	.0197	0.271
Male Dummy	-1.2941	1.4970	0.387
Age	-0.1136 **	0.0516	0.028
University Dummy	-2.0443	1.5552	0.189
Water Restrictions Dummy	2.1272	1.7693	0.229
Believe Scientists Drought Predictions Dummy	8.2996*	1.6190	0.000
Heard of Reclaimed Wastewater Dummy	4.0026*	1.5093	0.008
Do Not Agree with Use of Reclaimed Water for Toilet Flushing	-2.1411*	.6648	0.001
Households with Kids under 18 Dummy	2.1690	1.6762	0.196
30% Water Restriction Dummy	1.3090	1.4955	0.381
Health Concern	0.0917	1.0761	0.932
Believe Others Reduce Water Use By Less than Requested Dummy	10.3665*	3.7135	0.005
Distrust	1.0643*	0.3343	0.001
Constant	10.6598**	5.2341	0.042
σ (scale)	21.2140*	0.7929	0.000
LLF= -2105.5076			
LR χ^2 (15) = 282.16 (p=0.000)			
ρ (correlation)	-0.1288	0.1118	0.255

* significant at 1% level; ** significant at 5% level

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Endnotes

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[2] Grafton and Ward (2008) find that mandatory outdoor water restrictions in Sydney in 2004-2005 result in economic losses of $235 million (2005 $AU), approximately equivalent to $150 per household or about one half of the average annual water bill in Sydney.

[3] Lawn watering is important to the average Canadian. A cross-Canada survey undertaken by Statistics Canada in 2006 reports that 76% of respondents with lawns and/or gardens indicate that they water them regularly and very few households use a sprinkler timer (Statistics Canada, 2007).

[4] The exact wording on the WTP question is as follows: "Yes, I am willing to pay $XX more on my water bill every month to pay for Option B that uses reclaimed water so supplement water supplies so that summer water use by myself and member of my community does NOT need to be reduced by YY%." Or "No, I am not willing to pay $XX more on my water bill every month for Option B. This means that my community will impose summer water restrictions leading to a 10 % reduction in my water use."