EVALUATING THE RELATIONSHIP BETWEEN HOUSEHOLD CHARACTERISTICS AND WATER DEMAND

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Abstract. When quantifying water consumption trends, studies divide consumers into categories based on observable characteristics before assessing their responsiveness to conservation strategies. Less attention is given to how consumers differ in their responses to policy based on underlying environmental attitudes. The purpose of this paper is to estimate how environmental consciousness influences water use at the household level. We want to know if the people who believe their consumption decisions affect the environment conserve more water than the people who make consumption decisions based on cost and convenience. If the motivation behind the conservation is to protect the environment, we refer to this as environmentally and socially motivated conservation (E&S). If it is centered on cost or personal convenience, we refer to it as cost and convenience motivated conservation (C&C). We hypothesize the E&S motivation to conserve will be related to lower household consumption across diverse scenarios. We accomplish this research through a series of regression models. The model results indicate households interested in conservation do consume less, however, households motivated to conserve for the environment do not respond differently across diverse scenarios than households motivated to conserve for cost and convenience.

INTRODUCTION

In urban water systems, individual household characteristics determine the effectiveness of demand-side management strategies (Billings & Day, 1989). Often, though, the responsiveness to regulations in water consumption at the individual household level is not well understood. Current studies focus on the interactions between policies and their effects on diverse consumer groups (M. E. Renwick & Green, 2000), however less attention is given to how consumers differ in their responses to policy based on their attitudes toward conservation. For example, … When quantifying consumption trends, research efforts tend to use criteria such as income, water-use level, restrictions, and landscape size to separate households into distinct groups (Willis et al., 2013). We use a new approach by estimating how environmental consciousness influences water use at the household level.

The goal of our investigation is to elucidate household beliefs that lead to lower consumption when demand management strategies are implemented. It is possible that consumption patterns are affected by underlying belief structures. For example, some households may respond to changes in precipitation more than to changes in price because the motivation to conserve is related to concern for the environment and not cost. In contrast, some households may respond more to price increases if the motivation to

conserve concerns the cost to the household. This suggests strategies to decrease urban water demand might need to be contingent on the belief structures of service recipients. Utility agencies may not be able to make convenience-motivated conservationists into environment-motivated conservationists, however, understanding the composition of demand may help policy makers plan for urban demand in a more precise manner.

Traditionally, studies have divided consumers into categories based on observable characteristics before assessing their responsiveness to conservation strategies. For example, Renwick and Archibald (1998) divide households into groups based on income and landscaping needs (such as …) and study the effects of water efficient technology, price increases, and non-price restrictions on consumption in each category. They find that raising the price of water mainly reduces consumption among lower-income households, whereas restrictions on use reduce demand in low-density households with higher landscaping needs. These results highlight the equity implications of using different policies and underscore the importance of considering household characteristics when developing demand side management strategies.

Kenney et al. (2008) examine how socio-demographic characteristics are related to the way households respond to price increases, rebates for water efficient technology, and restrictions on lawn watering during drought conditions. Their results indicate that policy effectiveness varies among user groups and across climactic (i.e., drought) conditions. It is possible that changes in water use may occur due to increased consumer awareness of water shortages, and changes in consumption may come about by changes in perceptions of the value of water. However, while this study explores the influence of demographic characteristics on demand, it does not investigate the impact of underlying environmental perspectives and beliefs.

Other studies expressly identify the effect of household environmental attitudes on consumption (Corral-Verdugo, et al., 2002; Jorgensen, Graymore, & O'Toole, 2009; Randolph & Troy, 2008). However, most of this research has focused on factors within utility agency control, such as price and restrictions, as well as factors outside agency control, such as weather and demographic characteristics, rarely considering the impact underlying behaviors and inclinations have on consumer response to policy. A model proposed by Arbues, Angel Bolsa, and Villanua (2016) explores the extent to which household attributes determine the adoption of water conservation practices, and constitutes a significant evaluation of the impact variables such as monthly income, city size, education level of household members, and climatic location of the city have on water use. Our research extends these assessments—by examining the effect of household environmental attitudes on water demand—and fills a gap in knowledge about the relationship between environmental attitudes and household consumption.

Arbues et al. (2016) attempt to identify the household factors that influence water saving behaviors. While such a question has many relevant applications for city planning and resource management, identification strategies used in their and other analyses are often lacking. The crux of the issue is the likely correlation between explanatory variables and error due to unobserved or confounding variables. This endogeneity can be alleviated

with a standard fixed effects model, but doing so necessitates the omission of time invariant factors, which may be useful in predicting and understanding demand. With these limitations in mind, we acknowledge the tradeoff between possibly biased coefficients and our ability to estimate them.

We examine whether people who believe their consumption decisions affect the environment conserve more water than do people who make consumption decisions based on cost and convenience. If the motivation behind the conservation is to protect the environment, we refer to this as environmentally and socially motivated conservation (E&S). If it is centered on cost or personal convenience, we refer to it as cost and convenience motivated conservation (C&C). Our principal research questions are: 1) Do altruistic conservationists conserve more? 2) Do altruistic conservationists respond differently to changes in the price of water? 3) Do they respond differently to changes in temperature and precipitation? We hypothesize that the E&S motivation to conserve will be related to lower household consumption across diverse scenarios.

METHODS

Survey Location and Household Characteristics

Our research uses responses from a survey conducted by the city of Fort Collins in Colorado where utility agencies have employed a mixture of demand side management strategies with varying degrees of success. The onset of a drought that lasted from 2002 through 2003 alerted the Colorado Water Conservation Board (a state agency) of the importance of implementing efficiency plans to manage water demand. The first efficiency or conservation program took place in 2010. In Fort Collins, water demand is split evenly between commercial and residential uses. Strategies for conserving water on the residential side of demand have included: 1) a program that employs home water efficiency reports, which resulted in a decrease in demand of 2.5% or 25 million gallons a year, and 2) an Increasing Block Rate (IBR) structure, which is designed to discourage use by increasing the price of water as individual household demand enters higher tiers.

To test our hypothesis that environmental attitudes influence consumption, we assessed how water use levels change with respect to household characteristics as reported in a citywide telephone survey. We used a set of linear regression models to evaluate the relationship between these characteristics and residential water demand. Specifically, we use pooled Ordinary Least Squares (OLS), OLS random effects and OLS fixed effects, as well as a segmented sample, and conclude by addressing the implications of our findings for the development of water demand management strategies.

Environmental Perspectives, Consumer Response to Price Increases and Customer Seasonal Consumption

Data We collected information for 1,000 residential customers from November 2011 through October 2014. Household survey responses were matched to the customers' billing data, which was provided by Fort Collins Utilities. In addition, the Fort Collins

Assessors Office provided assessor information, census data was collected from a U.S. Census in the American Community Survey, and temperature and precipitation information was taken from CoAgMet stations. After matching household survey responses across the different data sets, the number of households for which information was included in this study was reduced to 115. Although the sample is small there is no identifiable reason to suggest missing households are systematically related.

To conduct our analysis, we focused on a subset of questions that explored participant environmental perspectives. Survey respondents were asked to rate their effort in reducing water consumption for everyday activities on a scale from 0 (never try) to 9 (always try). Participants indicated if their interest in reducing consumption was attributable to any of the following considerations: impact to the environment, cost to the household, and comfort and convenience by rating each statement on a scale from 0 (completely disagree) to 9 (completely agree). We included this information in our assessment because we wanted to know if the motivations that underlie an individuals' conservation, either concern for the environment or cost to the household, affect water use. Finally, we investigated consumer response to price increases, and consumer seasonal consumption as evidenced by assessor, census, and weather data. The instructions and questions used in our analysis are the following:

Please rate your level of effort on a scale from 0 to 9, where 0 indicates that you never try to reduce or minimize the amount of water and electricity that you use and a rating of 9 indicates that you always try to reduce or minimize the amount of water and electricity that you use.

1) When considering whether to use water or electricity, I consider the environmental impact that my household's water and electricity use will have on the community.
2) When considering whether to use water or electricity, I consider the economic impact that my household's water and electric use will have on the community.
3) When considering whether to use water or electricity, I consider how much it will cost my household to use those services.
4) When considering whether to use water or electricity, I consider the comfort and convenience of those in my household.

Based on their responses households were classified as either *environmentally* motivated or *cost and convenience* motivated. If the sum of questions 3 and 4 were greater than the sum of responses to questions 1 and 2, households were labeled as *cost and convenience (C&C)* motivated. If the opposite was true, households were labeled *environmentally and socially (E&S)* motivated.

Models: Influence of Household Characteristics on Consumption

Our model of water demand at the household level builds on analytical tools found in previous research (Arbues et al., 2016; Kenney et al., 2008; Willis, et al., 2011). For robustness we use a number of model specifications consistent with previous work (Arbues et al., 2016; Kenney et al., 2008; and Willis et al., 2011). Specifically, we

estimate the relationship between household characteristics and water use with four models: pooled OLS, OLS fixed effects with interaction terms, OLS fixed effects with a split sample, and an OLS seemingly unrelated regression as described by Blackwell, 2005.

Model 1) Pooled OLS

$$y_{it} = x_{it}\beta + h_i\gamma + b_i\rho + \mu_{it}$$

Where y_{it} is the amount of water or electricity consumed. x_{it} is a vector of explanatory variables including price, average daily temperature, and precipitation. h_i is a vector of time invariant household characteristics. b_i is a vector of question responses where each element takes a value of 0 to 9. β, γ and ρ are coefficients to be estimated.

Model 2) OLS fixed effects interactions

$$y_{it} = x_{it}\beta + d_i x_{it}\gamma + \alpha_i + \mu_{it}$$

Where y_{it} is the amount of water or electricity consumed. x_{it} is a vector of explanatory variables including price, average daily temperature, and precipitation. d_i is a binary variable that takes a value of 1 if the household ranked as environmentally motivated and 0 if they are ranked as cost and convenience motivated. β and γ are coefficients to be estimated.

Model 3) OLS fixed effects-split sample

$$y_{it} = x_{it}\beta + h_i\gamma + b_i\rho + \mu_{it}$$

Where the model is identical to model one except that the sample is segmented into the different motivating classes and run separately from one another. This method allows for a simple chow test, to compare differences across coefficients between groups.

Model 4) SUR

$$y_{it} = x_{it}\beta + h_i\gamma + b_i\rho + v_{1i} + \mu_{it} \;; \quad i = 1,2,\dots,N_1$$
$$y_{it} = x_{it}\beta + h_i\gamma + b_i\rho + v_{1i} + \mu_{it} \;; \quad i = N_1 + 1,\dots,N_2$$

Where the model is identical to model one except that the sample is segmented into the different motivating classes and run separately from one another. This method allows for a simple chow test, to compare differences across coefficients between groups.

While the above models were run for robustness, our results will focus on the fixed effects interaction model because it reduces the chances of unobserved heterogeneity and the risk of biased estimates. However, fixed effects methods cause all time invariant information to be averaged out of the model and thus does not provide insight for many household characteristics and water use. Thus, we will also report results from the Pooled OLS model.

RESULTS

Our results suggest that when individuals state a strong preference to conserve, there is a significant reduction in monthly water use. However, consumption levels and demand

responses to weather and price do not seem to be affected by the underlying motivation for this conservation.

On average, we do see that individuals who are environmentally and socially motivated to conserve use less, but not significantly. Other characteristics between user types are also similar.

It was hypothesized in this study that positive preferences and beliefs about conservation would line up with lower consumption across diverse scenarios. The empirical evidence supports our hypothesis and demonstrates that when households are motivated to conserve they use less water and the changes are significant. Our model results are congruent with previous scholarship in this area. A study by Willis et al. (2011) found that of 437 households, those who reported positive attitudes toward conservation consumed significantly less water than their counterparts who reported only moderate levels of concern for the environment or conservation. However, our findings suggest households motivated to conserve for the environment do not save more than households motivated by cost or convenience. Conditional on the household trying to conserve, the rationale and the reasoning behind that conservation does not seem significant. Table 2 shows the response to weather and price variables and the interaction of these variables with an altruistic dummy. The only significant interaction coefficient is that of price.

Table 2.

VARIABLES	(1) 2FE-intercept
lag_ln_avg_price	-0.648***
	(0.0144)
summer_dummy	0.178***
	(0.0164)
precip_sum	-0.00193***
	(0.000218)
averagetemp	0.0299***
	(0.000679)
DOS	0.0428***
	(0.00184)
lag_ln_avg_price_int	0.0310
	(0.0228)
summer_dummy_int	0.0120
	(0.0276)
precip_sum_int	-0.000173
	(0.000360)
averagetemp_int	0.00122
	(0.00115)
DOS_int	-0.00341
	(0.00312)

Constant	3.659***
	(0.0738)
Observations	17,188
Number of households	437
R-squared	0.551

These above results are qualitatively similar when estimated with a pooled OLS model, although the sizes of coefficients are different. Because of the nature of this analysis, the results presented in Table 3 should be seen as strictly correlations, not causal relationships. While price is again significantly different across group types, both groups respond similarly to season and weather. One interesting result that could not be investigated using the fixed effects model, is the relationship between consumption and income across groups. It appears that E&S conservationists decrease consumption with increased income, while C&C conservationists increase consumption with income.

Table 3.

VARIABLES	(1) E&S Motivated	(2) C&C Motivated
lag_ln_avg_price	-0.998***	-1.149***
	(0.0160)	(0.0120)
summer_dummy	0.140***	0.102***
	(0.0255)	(0.0186)
oldhome	0.0141	-0.0346***
	(0.0138)	(0.0112)
newhome	0.0566*	-0.121***
	(0.0306)	(0.0262)
SF	0.000121***	0.000133***
	(1.38e-05)	(1.04e-05)
midclass_dum	-0.0292*	0.0126
	(0.0162)	(0.0108)
highclass_dum	-0.0311*	0.0361***
	(0.0163)	(0.0117)
tot_persons	0.0851***	0.0418***
	(0.00554)	(0.00357)
precip_sum	-0.00192***	-0.00165***
	(0.000330)	(0.000249)
averagetemp	0.0255***	0.0246***
	(0.00106)	(0.000764)
DOS	0.0400***	0.0444***
	(0.00290)	(0.00210)
Constant	1.466***	0.658***
	(0.120)	(0.0884)

Observations	5,984	10,934
R-squared	0.638	0.665

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

DISCUSSION

To investigate the hypothesis that environmental beliefs impact consumer behavior, we assessed how residential water demand changes with respect to household attitudes. We analyzed environmental perspectives, consumer response to price increases, and customer seasonal consumption levels. Our findings suggest households interested in conservation consume less water than do households interested in price. However, households motivated to conserve for the environment do not respond differently across diverse scenarios than households motivated to conserve for cost and convenience.

Limitations of this study include our identification strategy and sample size. It is possible that omitted explanatory factors may have had an effect on consumption or might provide alternative explanations of the results. Our analysis includes a small sample size of 115 households. However, there are no identifiable reasons to suggest missing households are systematically related. In addition, due to data limitations, we were not able to compare our results across multiple groups, or across time periods, such as before and after price increases or before and after temperature and precipitation changes.

Policy makers may not be able to change the motivations within a household to conserve (i.e., to place a greater value on water or the environment); however, understanding the composition of demand does have implications for potential long run environmental programs. If there are long-term effects in regard to altruistic conservation then there is a demonstrated need to understand the connection between environmental beliefs and increased benefit from efficiency programs. If people act differently based on underlying attitudes, this might have implications for how state and local agencies address conservation issues. Future research should focus on the long-term effects of altruistic conservation and test if a reversal in conservation policy would result in different consumption levels from E&S and C&C conservationists.

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LITERATURE CITED

Arbues, F., Angel Bolsa, M., & Villanua, I. (2016). Which factors determine water saving behaviour? evidence from spanish households. *Urban Water Journal, 13*(5), 511-520. doi:10.1080/1573062x.2014.994004

Billings, R. B., & Day, W. M. (1989). DEMAND MANAGEMENT FACTORS IN RESIDENTIAL WATER-USE - THE SOUTHERN ARIZONA EXPERIENCE. *Journal American Water Works Association, 81*(3), 58-64.

Corral-Verdugo, V., Frias-Armenta, M., Perez-Urias, F., Orduna-Cabrera, V., & Espinoza-Gallego, N. (2002). Residential water consumption, motivation for conserving water and the continuing tragedy of the commons. *Environmental Management, 30*(4), 527-535. doi:10.1007/s00267-002-2599-5

Jorgensen, B., Graymore, M., & O'Toole, K. (2009). Household water use behavior: An integrated model. *Journal of Environmental Management, 91*(1), 227-236. doi:10.1016/j.jenvman.2009.08.009

Kenney, D. S., Goemans, C., Klein, R., Lowrey, J., & Reidy, K. (2008). Residential water demand management: Lessons from Aurora, Colorado. *Journal of the American Water Resources Association, 44*(1), 192-207. doi:10.1111/j.1752-1688.2007.00147.x

Randolph, B., & Troy, P. (2008). Attitudes to conservation and water consumption. *Environmental Science & Policy, 11*(5), 441-455. doi:10.1016/j.envsci.2008.03.003

Renwick, M. E., & Archibald, S. O. (1998). Demand side management policies for residential water use: who bears the conservation burden? *Land economics*, 343-359.

Renwick, M. E., & Green, R. D. (2000). Do residential water demand side management policies measure up? An analysis of eight California water agencies. *Journal of Environmental Economics and Management, 40*(1), 37-55. doi:10.1006/jeem.1999.1102

Willis, R. M., Stewart, R. A., Giurco, D. P., Talebpour, M. R., & Mousavinejad, A. (2013). End use water consumption in households: impact of socio-demographic factors and efficient devices. *Journal of Cleaner Production, 60*, 107-115. doi:10.1016/j.jclepro.2011.08.006

Willis, R. M., Stewart, R. A., Panuwatwanich, K., Williams, P. R., & Hollingsworth, A. L. (2011). Quantifying the influence of environmental and water conservation attitudes on household end use water consumption. *Journal of environmental management., 92*(8), 1996-2009.