Household Adoption of Water Conservation and Resilience Under Drought: The Case of Oklahoma City

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Selected paper prepared for presentation at the Agricultural and Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014.

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Abstract

Having suffered through exceptional drought in 2011-2012, 38% of Oklahoma's area remained in moderate to extreme drought in January 2013 with the expectation that it would continue (Svoboda, 2013). Beginning in April 2013, the Oklahoma City Water Utilities implemented irrigation restrictions in order to cope with low levels in Lake Hefner, one of Oklahoma City's major water supplies. Having taken only this non-price watering approach, the utility desired information on current and likely adoption of indoor and outdoor conservation methods. Currently 60-70% of treated water in Oklahoma is used on lawns during July-August (Moss 2011). Savings of 35% - 70% are possible from changes in residential landscaping and improved management of outside watering, which often accounts for more than 50% of total residential water use (Hurd 2006). Oklahoma City delivers tap water to more than 580,000 citizens every day. Average daily water use is 110 million gallons, and the treatment plants pump a maximum of 203 million gallons of water in 24 hours. With the goal of understanding the factors that influence the adoption of water conservation programming, a telephone survey targeting Oklahoma City households was conducted from December 2013 and February 2014. The phone survey randomly sampled 800 households out of 120,000 and paired responses with actual consumption data and tax assessor property characteristics. A series of factors including attitudes toward drought, the type of home, household size, gender, age, education, and race as potential determinants of the adoption of indoor and outdoor water conservation fixtures and technology were analyzed.

Introduction

Over 91% of the state of Oklahoma was classified as under exceptional drought as of May 20, 2014 (Mesonet, 2014). When lake levels across Oklahoma City's water supply, drop below 50%, the city will implement mandatory 2 day per week watering restrictions (OKC, 2014). In Oklahoma, summer is the time when demand for water is the highest, as it usually sees high temperatures which prompt residents to demand more water for maintaining turfgrass and landscape plants. Over the long term, Oklahoma City seeks to induce conservation, particularly in outdoor irrigation through education and economic incentives for devices such as smart irrigation soil sensors and timers, such that demand for scarce supplies and developing new water sources is dampened.

This research investigates the determinants of households' adoption of water conservation practices for indoor as well as outdoor uses. Using household level data, the physical and attitudinal factors that affect household's willingness to install water conserving fixtures or to change irrigation practices to adapt to drought tolerant turf needs were examined. This paper examines variables including the type of home, household size, gender, age, education, race, income, ethnicity, size of yard, and homeownership status in order to determine how they influence household's adoption of water conserving fixtures and appliances and /or changing irrigation practices to adapt to drought turf needs. We will also determine how consumer perceptions of the drought and current consumption affect adoption of water conservation programs. This paper uniquely combines survey data with more accurate assessors' data on market value and household characteristics and utility level information on consumption during drought.

1. Literature Review

A great deal of research has been devoted to the issue of water conservation practices either at the farm level or at the urban household level. Berk et al. (1993) concluded that adoption of water efficient devices is strongly correlated with higher education, higher income, having a yard, and being the owner of the home.

The evidence for income effects on water conservation is mixed. Renwick and Archibald (1998) in their investigation of household data from two communities in California found a positive correlation between household income and the number of indoor water-efficient fixtures such as low-flow shower heads and low-flow toilets. However, they stress that a higher income decreased the probability of using a water-efficient irrigation technology, i.e., the existence of automatic irrigation resulted in higher consumption. Worthington and Hoffman (2006) argued that income, through its correlation with education, may be reflective of water conservation measures taken by the household itself through the purchase of water-conserving appliances and planting of drought-tolerant garden vegetation. Mansur and Olmstead (2012), using daily household consumption data that was separated into indoor and outdoor use in 11 urban areas in Canada and the United States, concluded that indoor consumption tends to be affected only by income and family size while outdoor use is price elastic during the wet season and price inelastic in the dry season. De Oliver (1999) found in San Antonio, TX (1995-1997) that high income and high education are negatively correlated with conservation. To the contrary, Hausman (1979) concluded that the effect of income on adoption of energy-efficient equipment was unclear, he pointed out that richer households were less likely to adopt conservation attitudes since they value the savings less than poor households. Looking at income, Martinez-Espineira et al. (2004) argued based on a studied case of Seville (Spain) that:" although water is a normal good, income is not a determinant factor to explain water use, and the parameter associated with the share of supernumerary income allocated to water expenses is not always significant". Age, education, and home ownership tend to increase the adoption of water conservation. Gilg and Barr (2006), and Berk et al. (1993) found that households that are advanced in age were more likely to be informed about water-saving options. Being a home owner positively influences the adoption of water conservation practices, as home owners are more likely to anticipate long term benefits associated with a rational use of water than renters (Millock and Nauges 2010). In addition, being metered for all water uses and charged a volumetric charge on water consumption is likely to reduce consumption compared to flat rate policies, ie, any volume of use for one price (Millock and Nauges 2010, Renwick and Archibald 1998). Oklahoma City Utilities charges a metered constant rate per volume of $2.65 per 1,000 gallon, a volumetric rate that is relatively low for the state. Literature shows that inclining block rates encourage conservation if higher rates are set at an appropriate level and Oklahoma City may consider this option in the future (Adams et al.2009).

When looking at home age, Mansur and Olmstead (2012) concluded that old and new homes may use less water than "middle aged" homes. They argued that old homes may have smaller connections to water systems and fewer water-using appliances, such as dishwashers and hot tubs, than newer homes. Newer homes may have been constructed with water-conserving toilets and showerheads.

The innovation of this study lies on the fact that it investigates whether households adapt to increasing utility demands following drought given increased irrigation needs and their perceptions of drought and climate change. Understanding risk also requires an understanding of behavior to adapt, mitigate or prevent the potential behavior and impacts of climate change (Botzen and Van den Berg 2012; Longo et al. 2012).

2. Conceptual Framework and Hypothesis

We hypothesize that adoption of water conservation is affected by a series of factors such as education, income, gender, size of yard, home ownership status, resident's age, house age, the type of turfgrass, and the number of people in the house (Table 1). We expect respondents with greater education, home ownership, older age, and females to be more likely to adopt water conservation practices. We expect older, more educated individuals to be more frugal, aware of possible conservation and more able to tackle installation of water conservation features. We expect the size of yard and age of the house to negatively affect adoption of water conservation. The intuition is houses with larger yard size would probably use more water for their lawn maintenance; as a consequence they would be less likely to adopt water saving behaviors. We expect the effect of household size to be negative as households with younger residents are more concerned with high quality lawns and have less income per resident to enact adoption. Finally, we expect attitudes toward drought to affect adoption. Residents who think that the probability of their area suffering a prolonged drought will tend to adopt water conservation practices as a result of their perception of drought and climate change. We also expect that greater indoor and outdoor consumption during the 2012 drought will affect likelihood of adoption.

Table 1. Hypothesis Table Summary of Effect of Variables on Indoor and Outdoor Adoption

Variable	Measure	Expected effect on adoption
Education	Level of education	+, the more educated the household is the more likely to adopt
Homeownership	Owner=1, renter=0	+ ,Owners are more likely to adopt then renters
Size of yard	square feet	-,The larger the size of the yard the harder to adopt
House age	years	-,The older the house the less likely to adopt
Resident's age	years	+,The older the resident the more likely to adopt
Gender	If male=1, other=0	-,Male are less likely to adopt than female
Household size	Number of people in the house	-,As the number of people increases the harder it gets to adopt
Probability Drought Increasing	Yes=1, No=0	+,Residents who perceive an increase in the probability of drought will tend to adopt

3. Methodological Model

Adoption models are split into two categories in this paper, indoor and outdoor. Because adoption of either technique is rare in Oklahoma, adoption in each of the two categories is bundled as adopting any or multiple technologies as adoption and none as non-adoption. Adoption of a specific water conservation practice was modeled with a binary variable which takes the value of 1 if the practice is adopted and 0 if it is not (Greene, 2000). Suppose that Y_a and Y_{na} respectively represent individual's utility of two choices, adoption and non-adoption of water conservation practice, which might be denoted as U^a andU^b. The observed choice between the two reveals which one provides the greater utility, but not the unobservable utilities. Hence, the observed i indicator equals 1 if $U^a > U^b$ and 0 if $U^a \leq U^b$, i.e., non-adoption. Linearized, this is as follows (Greene, 2000):

$$U^a = \beta_a X + \varepsilon_a \; and \; U^b = \beta_b X + \varepsilon_b \tag{1}$$

Then, if we denote by $Y = 1$ the individual's adoption of water conservation practice a, we have (Greene, 2000):

$$Prob[Y = 1 \,|\, \mathrm{X}] = \mathrm{Prob}[U^a > U^b] \tag{2}$$

$$= Prob[\beta_a X + \varepsilon_a - \beta_b X - \varepsilon_b > 0 \,|\, \mathrm{X}] \tag{3}$$

$$= Prob[(\beta_a - \beta_b)X + \varepsilon_a - \varepsilon_b > 0 \,|\, \mathrm{X}] \tag{4}$$

$$= Prob[(\beta X + \varepsilon > 0 \,|\, \mathrm{X}], \text{where } \beta = \beta_a - \beta_b, and \; \varepsilon = \varepsilon_a - \varepsilon_b \tag{5}$$

$$= F(X\beta), where \; F(X\beta) \; represents \; a \; cumulative \; distribution \; function \tag{6}$$

Logit Model

The logit model was used and the errors are assumed to follow a logistic cumulative distribution (Feder and Umali 1993). Four separate estimations of the probability of adoption, indoor and outdoor technology adoption were conducted. Models I and II predicted the likelihood at indoor adoption, where the second model uses the additional variables for actual indoor consumption for 2012 and the belief of a persistent drought. Models III and IV predicted the likelihood of outdoor adoption, with the fourth model using actual outdoor consumption for 2012 and belief of a persistent drought. For outdoor water conservation, adoption was considered to have occurred if the household had adopted any of one of the following practices: the use of catch cups to audit irrigation, i.e., measure how much water has been used, measurement of how uniformly the yard is watered, the purchase of drought-tolerant lawn and/or garden plants, and/or finally the use of rain barrels and/or cistern to collect water for reuse. For the indoor water conservation dependent variable, the household was considered an adopter if it had installed any of the following technologies: low-flow or water sense labeled faucets or showerheads, ultra–low flow or water-sense toilet, and/or water-conserving or energy star certified dishwasher. Indeed, research shows that domestic water-saving devices (for example the adoption of low-flow toilets, showerheads, and faucets) and certain garden irrigation technologies reduce water consumption significantly (Renwick and Archibald, 1998; Chesnutt et al., 1992). The logit model is defined as follows:

$$P(Y=1)=\frac{\exp(X\beta)}{1+\exp(X\beta)}, \qquad (7)$$

Where Y equals 1 if one of the conservation methods is adopted and 0 otherwise and X is the row of independent variables and β is the corresponding parameter vector of coefficients that affect the likelihood of adoption.

DATA AND RESULTS

This study used household level water indoor and outdoor conservation technique adoption data collected from 797 households in Oklahoma City Oklahoma. During December through February 2014, the “Oklahoma Household Water Conservation Preference Telephone

Survey" was administered to Oklahoma City Water Utilities' customers to gather information on water conservation technology adoption and demographic statistics. From contact information provided by Oklahoma City Billing records, 3,333 valid numbers were contacted five times and of these, 2,308 declined to participate. In the end, a total of 803 surveys were completed with a final number of 797 useable surveys. The response rate was 24.09% based on contacted households. Completed surveys were then matched with consumption data from actual customer records for January 2012 - March 2014 (Xie, 2014) and mapped in a geographic information system (Arc 9) with Oklahoma County Assessor's Data for 2011 to obtain house market value, accurate house age, square footage and parcel square footage (Bryan, 2014). Table 2 provides definitions and units of measurement for the dependent and independent variables.

Table 2. Definitions of Dependent and Independent Variables Used for Logit Estimation

Dependent Variable	Definition
Indoor adoption	Low-flow or water sense labeled faucets or showerheads.
	Ultra –low flow or water-sense toilet.
	Water-conserving or energy star certified dishwasher.
Outdoor adoption	The use of catch cups to measure how much water has been used and how uniformly the yard is watered.
	The purchase of drought-tolerant lawn and/or garden plants.
	The use of rain barrels and/or cistern to collect water for reuse.

Independent Variables	Definition
Likelihood prolonged drought increasing	If yes=1, if no=0
Winter avg water consumption 2012	Jan, Feb, March cons., 1000s of gallons
Summer avg water consumption 2012	June, July, Aug. cons., 1000s of gallons
Number of people in the house	Household size
High school graduate	if yes=1, if no=0
Some college	if yes=1, if no=0
College graduate	if yes=1, if no=0
Advanced degree	if yes=1, if no=0, JD, MS, PhD.
Homeowner	if yes=1, if no=0
Age	Residents Age in Years
Resident's age	
Age	Resident's Age
Gender	if male=1, otherwise=0
Black	if yes=1, if no=0
Asian	if yes=1, if no=0
Other Races	if yes=1, if no=0, Native American, Multi-Racial
Hispanic	if yes=1, if no=0
Yard size	in square feet
Yard size squared	in square feet
House size	in square feet
House age	in years
House age squared	in years
Bermuda	if yes=1, otherwise=0, Type of Turf
Market value	Dollars, 2011 US, Assessed
Income $40,001-$75,000	Household income level (if yes =1, if no=0)
Income above $75,000	Household income level (if yes =1, if no=0)

Table 3 provides summary statistics of the variables for the sample. The sample is disproportionately educated compared to most Oklahomans. Six percent of households that responded to the survey have some high school education, while 17% have a high school diploma. 29% of households have some college education, while 28% have a college degree (BA /BS). In addition, 18% of households reported having an advanced degree. The 2012 US Census reports 85% of Oklahoma City's residents have a high school diploma and 28% have earned a Bachelor's degree (Census, 2014). The average age was 54 years. Looking at house age, on average respondents live in a house that is 43 years old with a standard deviation of 16.87 years. The average number of residents in a household was 3. The sample is disproportionately female at 60% and made up of homeowners at 86%. Roughly 54% of sampled households earn under $40,000, 25% have an income between $40,001-75,000 annually, and 21% of households earn over $75,001 dollars.. For reference, the 2012 U.S. Census reports median household income as $45,704/year for the period 2008-2012 and 17.6% of residents live below the poverty level Oklahoma City (U.S. Census Bureau, 2014). Out of 794 people who responded to the survey, 69.89% are white, 11.71% are Black or African-American, 3.43% are Asian, and 14.91% are of other races (Native Americans, Multi-Racial, others). The sample is fairly representative of race as reported in the 2010 U.S. Census which reports 62.70% of Oklahoma City residents were white, 15.10% Black or African American, and 6.3% of other races (American Indian &Alaska Native, two or more races). (U.S. Census Bureau, 2014). Looking at the sample, 8.56% of respondents are Hispanic. However, 17.20% of Oklahoma City residents identified themselves as Hispanic in the 2010 (U.S. Census Bureau, 2014). The survey was administered in Spanish upon request.

Table 3. Sample Descriptive Statistics

Variables	Definition	N	Mean	Std. Dev.	Min.	Max.
Outdoor adoption	if adopted =1, otherwise=0	794	32.75%	46.96%	0	1
Indoor adoption	if adopted =1, otherwise=0	794	30.98%	46.27%	0	1
Likelihood area's prolonged drought increasing	If yes=1, if no=0	794	38.92%	48.79%	0	1
Winter avg water consumption 2012	Jan, Feb, March cons.	783	5.14	4.10	0.33	59.67
Summer avg water consumption 2012	June, July, Aug. cons.	783	10.10	9.76	1.33	80
Winter avg water consumption 2013	Jan, Feb, March cons.	783	5.24	4.07	0.33	51.67
Summer avg water consumption 2013	June, July, Aug. cons.	783	7.69	6.35	0.33	52.66
Number of people in the house		792	3	2	1	17
some high school	if yes=1, if no=0	794	6.56%		0	1
High school graduate	if yes=1, if no=0	794	16.89%		0	1
Some college	if yes=1, if no=0	794	28.73%		0	1
College graduate	if yes=1, if no=0	794	28.46%		0	1
Advanced degree	if yes=1, if no=0	794	17.77%		0	1
Don't know level of education	if yes=1, if no=0	794	1.39%		0	1
Homeowner	if yes=1, if no=0	794	86.27%		0	1
Resident's age	in years	792	54.00	22.00	27	97
Gender	if male=1, otherwise=0	794	39.92%		0	1
White	if yes=1, if no=0	794	69.89%		0	1
Black	if yes=1, if no=0	794	11.71%		0	1
Asian	if yes=1, if no=0	794	3.43%		0	1
Other races (Native American, Multi-racial, others)	if yes=1, if no=0	794	14.97%		0	1
Hispanic	if yes=1, if no=0	794	8.56%		0	1
Yard size	in square feet	794	9781.09	46913.1	2139	1139130
Yard size squared	in square feet	794	229373738	4709518936	457532	1.2E+12
House size	in square feet	792	1459.94	2112.60	696	56525
House age	in years	787	43.39	16.87	6	108
House age squared	in years	787	2166.58	1681.34	36	11664
Bermuda	if yes=1, otherwise=0	794	54.53%	49.82%	0	1
Market value	in dollars	794	96847.71	94267.18	15400	1248941
Income below $40,000		794	53.52%	49.90%	0	1
Income level $40,001-$75,000		794	25.19%	43.47%	0	1
Income level above $75,001		794	21.08%	40.78%	0	1

Table 4 below illustrates household water consumption (thousands of gallons) for the 2012-2014 period. Household winter consumption was calculated by averaging individual monthly consumption for January, February and March. Summer consumption was calculated by averaging monthly consumption of June, July, and August. On average, winter consumption for 2012 was 5.14 thousand gallons with a maximum of 59.67 thousand gallons. For the summer of the same year, average water consumption was 10.1 thousand gallons with a maximum of 80 thousand gallons. . Therefore, the summer incremental consumption was on average 4,960 gallons per household in summer for outdoor irrigation and activities, almost 50% of average summer consumption. Water conservation stands to increase much more from outdoor adoption to reduce summer consumption, but as the results will show, consumers by far have embraced indoor technologies sooner than outdoor conservation. Winter consumption for year 2013 was 5.24 thousand gallons on average with a maximum of 51.67 thousand gallons, and summer consumption was 7.69 thousand gallons with a maximum of 52.66 thousand gallons.

Table 4. Average OKC Residential Water Consumption (1000s of Gallons). N=783

	Mean	Std. Dev.	Min	Median	Max
Winter 2012	5.14	4.1	0.33	4.33	59.67
Summer 2012	10.1	9.76	1.33	7	80
Winter 2013	5.24	4.07	0.33	4.33	51.67
Summer 2013	7.69	6.35	0.33	6	52.66
Winter 2014	5.18	5.44	0.33	4	90.00

In this research, a household’s adoption of water conservation practices through indoor and outdoor uses was studied. For outdoor water conservation, whether a household has adopted either one of the following practices: the use of catch cups to measure how much water has been used and how uniformly the yard is watered, the purchase of drought-tolerant lawn and/or garden plants, and finally the use of rain barrels and/or cistern to collect water for reuse was evaluated. For indoor water conservation, whether a household had installed either one of the following: low-flow or water sense labeled faucets or showerheads, ultra –low flow or water-sense toilet, and finally water-conserving or energy star certified dishwasher was evaluated. Table 5 shows estimated coefficients for a logistic models using SAS 9.3. Four models were estimated; model 1 and model 3 are the reduced or basic models and models 2 and 4 are the expanded models for outdoor and indoor conservation respectively with perception of drought and actual consumption added. Table 6 shows the Odds Ratio Estimates for Models 1-4 with the level at which they were significant. Models 1 and 2 correctly predicted outdoor adoption in 79.8% and 79.9% of the cases, whereas the indoor adoption models predicted 63.3% and 64.9% respectively (Table 5).

Outdoor Adoption (Models I -2)

For the outdoor adoption of water conservation as shown in models 1, and 2, a resident that has adopted indoor conservation methods is likely to adopt an outdoor practice (significant at the 99% confidence level in both models). In fact, a respondent that adopted an indoor practice is 5.31 and 5.41 times more likely to adopt an outdoor conservation practice than one who has not in models 1 and 2 respectively. Education at all levels above high school is significant in models 1 and 2 at the 90 to 99% confidence levels when compared to those with less than high school, the dropped variable (Table 5). Compared to someone without a high school degree, a respondent with some college, college graduate or advanced degree are 2.61, 3.6 and 6.69 times more likely to adopt an outdoor conservation technique respectively. Outdoor adoption of water conservation is increasing in respondent's age and is significant at the 90% level in both models. For each year increase in respondent age, there is a 1.01 odds of adoption. . Compared to Caucasians, African Americans/Blacks respondents were less likely in both model 1 and 2 to adopt outdoor water conservation at the 90% significance level. Actually, the odds for adopting outdoor water conservation practices is 54% less for African American/Blacks compared to Caucasians. None of the other race or ethnicity variable proved significant. Yard size and house size variables were not significant, nor was market value. Those who identify lawn as predominantly Bermuda grass were more likely to adopt water conservation behaviors. In fact, those residents who have Bermuda grass on their lawn were 1.9 times more likely to adopt outdoor water conserving behavior than residents that did not have Bermuda grass. Surprisingly neither gender, nor homeownership, were significant, but the signs are as expected, i.e., we expect vested residents and men to both be more likely to adopt outdoor conservation. Income levels above $75,000 did significantly and positively affect adoption at the 99% confidence level. The odds for adopting outdoor water conserving behavior for residents with income above $75,000 compared to those with incomes below $40,000 is 1.86 times more In the expanded model for outdoor adoption, model 2, neither the belief in the likelihood of drought, nor summer consumption during summer of 2012 proved significant (Table 5).

Indoor Adoption (Models 3-4)

Similar results to the outdoor adoption model are found for models 3 and 4 for indoor adoption as shown in Table 5. In both the basic (model 3) and enhanced models (model 4), for all levels of education above high school, there was a significant likelihood of adoption when compared to those with less than a high school education, holding all else constant. For the basic model, homeowners were more likely to adopt indoor conservation fixtures at the 99% confidence level. In fact, the odds of adopting indoor conservation fixtures was about 1.65times higher for homeowners than for residents that were not owners; however, this variable was not significant in model 4. House age in model 3 was more likely to negatively and significantly affect adoption of fixtures which seems inconsistent with the idea of renewing old fixtures with new as a house ages, but perhaps owners of older homes do not invest in more expensive features. And income level above $75,001 per year per household is significantly more likely to adopt indoor conservation fixtures compared to households earning less than 40,000 at the 99% confidence level, but this was true only in model 4, with an odds ratio of 1.32 implying that the odds for adopting indoor conservation fixtures was 32% higher for residents with income level above $75,001 making less than $40,000.

Surprisingly, market value, house square footage, and number of individuals in the home, and winter consumption were not significant in the indoor models 3-4. None of the ethnicity or race variables were significant. The belief that there would be a prolonged drought does significantly affect the likelihood of indoor adoption in the enhanced model 4 at the 99% confidence level. In fact with an odd ratio of 1.54, residents that believed that there would be a prolonged drought were 1.54 times more likely to adopt indoor water conservation fixtures than those who did not agree.

Table 5. Indoor and Outdoor Adoption Logit Estimations (Models I-IV)

	Model 1 (Outdoor)		Model 2 (Outdoor)		Model 3 (Indoor)		Model 4 (Indoor)	
Variable	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Intercept	-3.31***	0.82	-3.42***	0.83	-1.23*	0.68	-1.41**	0.69
Indoor adoption	1.67***	0.18	1.69***	0.19				
Likelihood area's prolonged drought increasing			0.15	0.18			0.43***	0.16
Winter avg water consumption 2012							-0.003	0.02
Summer avg water consumption 2012			0.01	0.01				
Enrollment in Price smoothing averaging	-0.004	0.19	0.0003	0.19	-0.06	0.17	-0.05	0.17
Number of people in the house	-0.02	0.06	-0.03	0.07	-0.01	0.004	-0.02	0.05
High school graduate	0.88	0.54	0.86	0.54	0.39	0.43	0.36	0.43
Some college	0.96*	0.52	0.91*	0.52	0.97**	0.41	0.94**	0.41
College graduate	1.28**	0.53	1.26**	0.53	0.84**	0.42	0.79*	0.42
Advanced degree	1.9***	0.54	1.84***	0.55	0.88**	0.44	0.77*	0.44
Homeowner	0.04	0.35	0.05	0.35	0.98***	0.3	0.97	0.31
Resident's age	0.01**	0.005	0.01**	0.004	-0.005	0.004	-0.005	0.004
gender	0.26	0.18	0.24	0.19	0.1	0.16	0.13	0.17

Notes: ***=significant at the p<0.01 level, **=significant at the p<0.05 level, *=significant at the p<0.10 level

Table 5. Indoor and Outdoor Adoption Logit Estimations (Models I-IV) Continued

	Model 1 (Outdoor)		Model 2 (Outdoor)		Model 3 (Indoor)		Model 4 (Indoor)	
Variable	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Black	-0.77**	0.33	-0.74**	0.33	-0.09	0.26	-0.07	0.26
Asian	-0.16	0.77	-0.1	0.78	-1.12	0.82	-1.01	0.83
Other races (Native American, Multi-racial, other)	-0.48	0.32	-0.45	0.32	0.04	0.27	0.06	0.27
Hispanic	0.52	0.45	0.50	0.45	-0.34	0.38	-0.36	0.38
Yard size	3.99E-12	0.000016	1.08E-06	0.000016				
Yard size squared	-2.60E-11	4.95E-11	-162E-13	5.19E-11				
House size					-0.00005	0.0001	-0.00005	0.0001
House age	-0.008	0.02	-0.01	0.02	-0.03*	0.02	-0.03	0.02
House age squared	-0.00001	0.0002	8.46E-06	0.0002	0.0002	0.0001	0.0002	0.0001
Bermuda	0.64***	0.19	0.62***	0.19				
Market value	1.79E-07	1.16E-06	-3.01E-07	1.24E-06	-3.59E-07	1.37E-06	-2.74E-07	1.40E-06
Income level $40,001-$75,000	-0.15	0.23	-0.14	0.23	0.23	0.2	0.25	0.20
Income level above $75,001	0.62***	0.24	0.63***	0.24	0.22	0.22	0.28***	0.22
N	787		783		787		783	
LR Chi2	197.53		200.09		48.55		56.75	
Prob Chi2	<0.0001		<0.0001		0.0001		<0.0001	
Log Likelihood	-388.49		-385.72		-472.88		-465.45	
Pseudo R2	20%		21%		5%		6%	
% Correctly predicted	79.8%		79.9%		63.3%		64.9%	

Table 6. Odds Ratio Estimates (Models I-IV)

	Model 1 (Outdoor)	Model 2 (Outdoor)	Model 3 (Indoor)	Model 4 (Indoor)
Variable	Point Estimate	Point Estimate	Point Estimate	Point Estimate
Indoor adoption	5.31***	5.41***		
Likelihood area's prolonged drought increasing		1.16		1.54***
Winter avg water consumption 2012				1
Summer avg water consumption 2012		1.01		
Enrollment in Price smoothing averaging	1	1	0.94	0.95
Number of people in the house	0.98	0.97	0.99	0.98
High school graduate	2.41	2.36	1.48	1.43
Some college	2.61*	2.48*	2.64**	2.6**
College graduate	3.6**	3.53**	2.32**	2.20*
Advanced degree	6.69***	6.3***	2.41**	2.16*
Homeowner	1.04	1.05	2.66***	2.64
Resident's age	1.01**	1.01**	1	1
gender	1.3	1.27	1.11	1.14

Notes: ***=significant at the $p<0.01$ level, **=significant at the $p<0.05$ level, *=significant at the $p<0.10$ level

Table 6. Odds Ratio Estimates (Models I-IV) Continued

	Model 1 (Outdoor)	Model 2 (Outdoor)	Model 3 (Indoor)	Model 4 (Indoor)
Variable	Point Estimate	Point Estimate	Point Estimate	Point Estimate
Black	0.46**	0.48**	0.91	0.93
Asian	0.85	0.90	0.33	0.36
Other races (Native American, Multi-racial, other)	0.62	0.64	1.04	1.06
Hispanic	1.68	1.65	0.71	0.7
Yard size	1	1		
Yard size squared	1	1		
House size			1	1
House age	0.99	0.99	1*	0.97
House age squared	1	1	1	1
Bermuda	1.9***	1.86***		
Market value	1	1	1	1
Income level $40,001-$75,000	0.86	0.87	1.26	1.28
Income level above $75,001	1.86***	1.88***	1.25	1.32***

Likelihood ratio tests were performed to compare model 1 to 2, and model 3 to 4 to determine whether any of the basic/reduced models fit significantly better than the full model. The likelihood ratio test between model 1 and model 2 tests the null hypothesis restriction that the dummy variable "likelihood area's prolonged drought increasing" and "summer average water consumption 2012" are equal to zero. For outdoor adoption of water conservation, the likelihood ratio test statistic is equal to 974.51-971.53 = 2.98. With a $\chi^2(0.05; 24\text{-}22) = 5.99 > 2.98$, the two attitude questions in the outdoor adoption of water conservation should not be added to the model, therefore the reduced model (model 1) is the appropriate one. The likelihood ratio test between model 3 and model 4 was almost the same as the initial one, except the hypothesis restriction included winter average water consumption 2012 instead of summer. For indoor adoption of water conservation, the likelihood ratio test statistic is equal to 994.32-988.26=6.06. The Chi-Square statistic is $\chi^2(0.05; 21\text{-}19) = 5.99$. Since 6.06 > 5.99, the threshold for the test, the two attitudinal questions regarding the resident's area suffering a prolonged drought and spring average water consumption should be added to the regression model, therefore model 4 (the full model) should be kept.

Conclusion

This article has focused on the determinants of household adoption of water conservation technologies and practices using demographic, house characteristics, attitudes and water consumption data gathered from Oklahoma City water utilities customers. Based on the outcomes from the logit models, we may assert that education and upper income levels are contributing factors in explaining both indoor and outdoor adoption of water conserving behavior. We have found a threshold at which the variable income leads to the adoption of water conserving behavior. Indeed, households making more than $75,000 a year were more likely to adopt indoor, as well as outdoor water conservation practices, compared to households making less than $40,000. We did not find enough evidence to support the claim that the size of the yard affects outdoor adoption of water conservation, but households that have Bermuda grass as the type of turfgrass in their lawn are more likely to adopt water conserving behavior compared to households that have other types of turfgrass in their lawn.

Many of the included assessor's characteristics such as house age, market value, and house size were insignificant in both the indoor and the outdoor adoption models, except in model 3 for indoor conservation where residents in older houses were less likely to adopt indoor fixtures. Gender, race, and ethnicity proved to be insignificant except for African American households, which were less likely to adopt outdoor conservation, and older residents which were more likely to adopt outdoor but not indoor conservation.

Attitudes and consumption only mattered for indoor adoption of fixtures, but those who adopted indoor water conserving fixtures were significantly more likely to adopt outdoor conservation measures. We could not support the claim that household's perception of increasing drought affects adoption of water conservation except for the enhanced model for indoor conservation (model 4). When adding household water consumption and the household's perception of increasing drought, the likelihood ratio test revealed that they only made a difference for indoor adoption of water conservation and not for outdoor adoption of water conservation.

Consumption variables did not have the expected effect in 2012, perhaps because rates continued to be low per 1000 gallons consumed. Our research on training residents about outdoor conservation suggests that our results for outdoor adoption make intuitive sense. The act of auditing the yard and researching plants requires thought and research on the part of the homeowner, suggesting that education and increasing access to information about consumption will aid Oklahoma City's effort for demand side management. In fact, as Sutherland (1991) noted: "Policies that encourage the dissemination of information, such as appliance labelling, may promote energy efficiency and overall economic efficiency". Indoor conservation has benefited from labelling systems such as watersense ™ labeling which is visible at the time of purchase and in advertising (EPA, 2014). By contrast, outdoor irrigation systems with smart technology are largely installed at arm's length from the consumer.

Further research is still needed to help understand other factors that contribute to household's adoption of water conservation behavior. We believe that the more we know about household's behavior toward water conservation, the easier it would be for the Oklahoma City Water Utility using this research as a background for its decision making process to enact an effective and productive water conservation policy.

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