Drivers of Price and Nonprice Water Conservation by Urban and Rural Water Utilities: An Application of Predictive Models to Four Southern States

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This study examines water system characteristics, managers' attitudes and perceptions toward water conservation, and future planning strategies that influence the adoption of water conservation programs for urban and rural communities. We surveyed water system managers in Oklahoma, Arkansas, Tennessee, and Florida; and we parameterized predictive adoption models for price-based (PC) and nonprice-based (NPC) conservation programs. Notably, results suggest that information about the price elasticity of water demand for a community does encourage PC and NPC adoption; and we found no evidence that PC and NPC adoption is jointly considered by water systems.

Key Words: predictive models, southern US, water conservation, water system managers

JEL Classifications: Q24, Q30, Q50

Water systems in the southern United States are confronting periodic water shortages caused by droughts, population growth, and diminishing access to traditional supply sources (Council

for Agricultural Science and Technology, 2009; Kenny et al., 2009; McNulty et al., 2008; Seager, Tzanova, and Nakamura, 2009). It is anticipated that the region's water demand will continue to increase, putting additional pressure on constrained water supplies (Elcock, 2010). Historically, water supply capital investment projects such as new reservoirs were the solution to meeting growing water demands (Kenney et al., 2008). However, these projects can be extremely costly, take several years to complete, and increasingly run afoul of state and federal environmental regulations (Gleick, 2000). For these reasons, some recent major water projects in the United States are considered economically "inefficient" (Olmstead, 2010). That is, additional water from these sources is relatively expensive compared with other approaches to dealing with water shortages. An alternative approach to dealing with water shortages is to implement

water conservation programs that are aimed at reducing per-capita water use (Gleick, 2003; Kenney et al., 2008). Recently, southern US states began using water conservation programs to manage water supplies (Mullen, 2011).

Water conservation programs are often classified into price conservation (PC) and nonprice conservation (NPC) programs. PC programs use the increase in the price of water to create an incentive to reduce end-users' water consumption. Some examples of PC programs include an inclining block rate structure, seasonal pricing, excess use rate, indoor/outdoor rate, and scarcity pricing (Adams, Boyer, and Smolen, 2009; Vickers, 2001). On the other hand, NPC programs reduce end-users' water consumption or increase water use efficiency without changing water prices. Several creative NPC programs have been developed such as rebates to purchase low-flow devices, outdoor watering restrictions, leak control, education/awareness, and retrofitting devices to replace less efficient water devices (Vickers, 2001).

Extant literature tends to focus on the effectiveness of water conservation programs at reducing water demand (e.g., Inman and Jeffrey, 2006; Olmstead and Stavins, 2009). Studies of PC programs usually involve the estimation of price elasticity of water demand before and after the implementation of a PC program. Effectiveness is measured by the percentage change in water use for the given percentage change, usually an increase, in the price of water (e.g., Brookshire et al., 2002; Dalhuisen et al., 2003; Espey, Espey, and Shaw, 1997). Meta-analyses by Brookshire et al. (2002) and Espey, Espey, and Shaw (1997) found that water use drops by roughly 0.5% after a 1% increase in water prices (Table 1), and Dalhuisen et al. (2003) found an average price elasticity of residential water demand of –0.41 (i.e., a 0.41% drop in water use for every 1% increase in water prices). Similarly, the effectiveness of NPC programs is usually measured by changes in water use after the implementation of the NPC program (e.g., Kenney et al., 2008; Michelsen, McGuckin, and Stumpf, 1999). Among available NPC programs, mandatory and voluntary water restrictions, installation of low-flow devices, and education/awareness programs have received the most

attention in the literature. However, accurate water use data pre- and postimplementation of NPC is difficult to obtain, resulting in a wide range of estimates of effectiveness (Table 1). Joint implementation of two or more water conservation programs can also confound analysis of the individual effectiveness of each program.

A few researchers have gone beyond measuring the effectiveness of water conservation programs by adding a financial dimension to assessing water conservation programs. The cost-effectiveness of water conservation programs is normally measured by the volume of water use reduced during the life of a NPC or PC program relative to the cost of implementing the program. It is intuitive that communities would be interested in managing water demand at the least cost, especially communities with severely limited budgets. However, this can be a difficult goal to attain given the lack of available, accurate, and complete cost estimates for each water conservation program. As a result, the literature reports a wide range of estimates for cost-effectiveness of PC and NPC programs (Mansur and Olmstead, 2007; Olmstead and Stavins, 2009; Timmins, 2003), but PC programs are generally considered to be more cost-effective than NPC (see comprehensive review by Olmstead, 2010).

Despite the lack of available data to evaluate effectiveness and cost-effectiveness of water conservation programs, particularly for small water systems, we know that water systems throughout the southern United States are adopting these programs (e.g., Boyer, Adams, and Lucero, 2010; Mullen, 2011). Given this lack of data, additional factors may play an important role in water systems' water conservation decisions. Several studies have examined characteristics of end-users that influence the underlying support for the adoption of water conservation programs by water systems (e.g., Atwood, Kreutzwiser, and de Loe, 2007; Cary, 2008; Hall, 2000; Kolokytha and Mylopoulos, 2002; McDaniels, Axelrod, and Cavanagh, 1998; Ward, Michelsen, and DeMouche, 2007). In some notable cases, public attitudes have been found to influence the decision to adopt water conservation. Ward, Michelsen, and DeMouche

Table 1. Past Studies that Examined Price and Nonprice Conservation

Conservation Program	Study	Effectiveness
Price—price elasticity of demand	Brookshire et al., 2002; Campbell, Johnson, and Larson, 2004; Dalhuisen et al., 2003; Espey, Espey, and Shaw, 1997; Gaudin, 2006; Hurd, 2006; Kenney et al., 2008; Olmstead, Hanemann, and Stavins, 2007; Renwick and Archibald, 1998; Wang et al., 1999; Worthington and Hoffman, 2008	Average of 5% reduction in water demand with a 10% increase in price
Nonprice—education/awareness	Campbell, Johnson, and Larson, 2004; Geller, Erickson, and Buttram, 1983; Howarth and Bulter, 2004; Inman and Jeffrey, 2006; Michelsen, McGuckin, and Stumpf, 1999; Wang et al., 1999; Syme et al., 2000	0–25% reduction in water demand
Nonprice—retrofit devices	Buckley, 2004; Campbell, Johnson, and Larson, 2004; Geller, Erickson, and Buttram, 1983; Michelsen, McGuckin, and Stumpf, 1999; Renwick and Archibald, 1998; Renwick and Green, 2000; Wang et al., 1999; White and Fane, 2002; Timmins, 2003	0–32% reduction in water demand
Nonprice—rebates	Howe and White, 1999; Michelsen, McGuckin, and Stumpf, 1999; Renwick and Archibald, 1998; Renwick and Green, 2000; White and Fane, 2002	0–10% reduction in water demand
Nonprice—outdoor watering restrictions	Halich and Stephenson, 2009; Howe and White, 1999; Mansur and Olmstead, 2007; Michelsen, McGuckin, and Stumpf, 1999; Olmstead and Stavins, 2009; Renwick and Archibald, 1998; Renwick and Green, 2000; Shaw and Maidment, 1988	19–29% reduction in water demand
Nonprice—efficient lawn irrigation systems	Hurd, 2006; Kenney et al., 2004; Kenney, Klein, and Clark, 2004; Mansur and Olmstead, 2007; Renwick and Archibald, 1998; Schuck and Profit, 2004; White and Fane, 2002	7–53% reduction in water demand

Note: Most studies include multiple nonprice conservation in the analysis, and some include both price and nonprice conservation.

(2007) indicated that residents' negative attitudes and perceptions about conservation can be a major barrier to conservation adoption even when benefits of conservation programs far exceed their costs. Atwood, Kreutzwiser, and de Loe (2007) noted that an outdoor water conservation program received positive support from residents in Guelph, Canada, whereas outspoken critics of the program led public officials to believe the opposite. In the late 1970s, Tucson, Arizona, was the first US city to set water rates equal to marginal cost of water supply. This resulted in a large price increase, and a year later, the entire city council was ejected from office (Hall, 2000). Similarly, demographic variables of residents such as house size, income, and education can influence the use of PC and NPC programs.

Only a few recent studies have focused on characteristics of water systems as drivers of

PC conservation adoption (Boyer et al., 2012; Hearne and Kritsky, 2010; Teodoro, 2009). Hearne and Kritsky (2010) found that water systems are more likely to adopt PC programs if their water system staff is involved in professional development activities and their board members attend water management conferences. Teodoro (2009) found that water managers who frequently attend professional conferences, read professional journal articles, consult with peers on policy issues, serve on professional committees, and have professional society memberships are more likely to adopt an inclining block rate (Teodoro, 2009). These studies imply that organizational structure and decision-making processes within a water system can influence the adoption of PC.

More recently, Boyer et al. (2012) assessed factors that drive water managers in four southern US states to adopt an inclining block rate versus a uniform rate and found that water systems confronted with increasing treatment costs are more likely to adopt an inclining block rate than a uniform rate structure. Conversely, water systems are more likely to switch to a uniform rate structure to increase their revenue streams, qualify for a government grant or loan, price water more equitably for all end-users, and invest in current or future infrastructure development. Promoting water conservation was found to be an insignificant factor in water systems switching to an inclining block rate. This is unanticipated because inclining block rate structures are commonly viewed as a conservation tool (Kenney et al., 2008; Olmstead, Hanemann, and Stavins, 2007; Teodoro, 2009). The results from this analysis suggest that water systems in the southern United States might not perceive an inclining block rate as an effective PC program.

Additionally, water systems' uncertainty about planning for future water demand and supply may also impact the adoption of conservation programs. Construction projects to expand supplies such as a new reservoir or additional water well are costly and can take several years to complete. However, expanding water supplies may ensure that water systems have sufficient supplies for future use; meanwhile, using conservation programs to manage water

supplies may not provide water systems the assurance of having sufficient supplies for the future (Maddaus, Gleason, and Darmody, 1996). Water conservation can help avoid expansion capital investment projects to enhance water supplies; thus, such efforts are important in planning for future water needs (Maddaus, Gleason, and Darmody, 1996; Mullen, 2011).

Although a few papers have partially explored the influence of various factors on water systems' adoption of PC programs, factors driving NPC adoption have been largely ignored in the literature. Our study addresses this gap in the literature and assesses water system characteristics, managers' attitudes and perceptions toward water conservation, and future planning strategies that may influence the adoption of PC and NPC programs, specifically by analyzing data from small and large water systems. This is a notable departure from existing water conservation literature, which focuses primarily on PC adoption by water systems and on water systems serving only large urban communities. Additionally, much of the water conservation research in the southern United States has focused on agricultural water (e.g., Ding and Peterson, 2012; Johnson et al., 2011; Jordan, 2008; Rister et al., 2011; Wheeler et al., 2008), and little is known about the adoption of water conservation programs in rural and urban southern US communities.

Subsequently, we 1) describe a conceptual model of the PC and NPC adoption decision by water systems; 2) review our survey design and data collection methods; 3) present three predictive econometric models of PC and NPC adoption; and 4) report and interpret our results, including implications of our findings on water conservation program design.

Conceptual Model of Water Conservation Programs Adoption

We model an individual water system's decision to adopt PC and/or NPC using a random utility model framework (e.g., Haab and McConnell, 2002). According to economic theory, the water system will select the water conservation alternative (e.g., PC, NPC, or none) that provides the highest net benefits to the system. We model the

adoption of PC and NPC as an independent decision made by a water system and also separately consider the adoption of PC and NPC as a jointly made decision by the system. A random utility model assumes that the net benefits, NB_i, that water system i derives from a water conservation program x is a linear function:

(1) $NB_i = (\delta_i^{'}\alpha)x + \varepsilon_i$

where $(\delta_i^{'}\alpha)x$ is a deterministic component of the water conservation program and observed characteristics of the water system, δ_i is vector of independent variables specific to water system i, α is a vector of parameters, and ϵ_i is a random error term. If we assume that water conservation decisions are made independent of one another, the probability of water system i choosing alternative A over B is:

(2) $P(A) = P[(\delta_i^{'}\alpha)(x^A - x^B) + \varepsilon_i^A - \varepsilon_i^B > 0]$.

Over $i = 1, \ldots, N$ water systems and for water conservation alternative $j = 1, \ldots, J$, the likelihood function is:

(3) $L(\alpha) = \prod_{i=1}^{N} \prod_{j=1}^{J} P_i(j)^{y_{ij}}$

where y_{ij} equals one if water system i adopted water conservation alternative j and zero otherwise.

Parameters α are econometrically determined to maximize the likelihood function (i.e., to fit the observed pattern of PC and NPC adoption in the data). When the decisions to adopt PC and NPC are independent, Equation (3) reduces to:

(4) $P(PC = 1) = \int_{-\infty}^{\delta_i^{'}\alpha_{PC}} \varphi(t)dt = \Phi(\delta_i^{'}\alpha_{PC})$

and

(5) $P(NPC = 1) = \int_{-\infty}^{\delta_i^{'}\alpha_{NPC}} \varphi(t)dt = \Phi(\delta_i^{'}\alpha_{NPC})$.

where Φ is the standard normal cumulative distribution function. $PC = 1$ if a water system switched to a inclining block rate pricing structure or switched to a higher uniform rate sometime in the last five years from the time the survey was completed to completing the survey; otherwise, $PC = 0$. We include a water system's decision to increase its uniform rate as PC adoption because increasing the price of water sends a conservation signal to end-users. $NPC = 1$ if a water system has used an education/awareness program, watering restriction, rebates on low-flow devices, retrofits, and xeriscaping incentives to reduce water use within five years of completing the survey; otherwise, $NPC = 0$. Parameter estimates from Equations (4) and (5) are used to test whether water system characteristics, managers' attitudes and perceptions toward conservation, and future water supply planning activities affect the probability of PC and NPC adoption.

Alternatively, we can specify the PC and NPC adoption decisions as being jointly determined (i.e., PC and NPC adoption decisions are not made independent of one another). In this case, a bivariate probit model is appropriate to evaluate the impact of the explanatory variables on PC and NPC program implementation (Greene, 2008). Now, the dependent variable includes three choices: 1) no conservation adoption; 2) PC adoption; and 3) NPC adoption; and is expressed as:

(6) $P(PC = 1, NPC = 1|\delta_i^{'}) = \Theta[\delta_i^{'}\alpha_{PC}, \delta_i^{'}\alpha_{NPC}, \rho]$

where Θ is the bivariate standard normal cumulative distribution function, and ρ is the tetrachoric correlation coefficient between the error term for the PC probit model ε_i^{PC} and the error term for the NPC probit model ε_i^{NPC} (Greene, 2008). If $\rho = 0$, the adoption of PC and NPC is an independent decision and Equation (6) reduces to a product of two univariate standard normal distributions of ε_i^{PC} and ε_i^{NPC} (Greene, 2008). The significance level and sign of ρ allow us to test if the decisions to adopt PC and NPC are made jointly as suggested by Kenney et al. (2008) and Renwick and Archibald (1998). Recall that $PC = 1$ if a water system switched to a inclining block rate pricing structure or switched to a higher uniform rate sometime in the last five years from the time the survey was completed; otherwise, $PC = 0$. $NPC =$ one if a water system

has used an education/awareness program, watering restriction, rebates on low-flow devices, retrofits, and xeriscaping to reduce water use sometime in the last five years preceding completion of the survey; otherwise, $NPC = 0$.

Data

We used a multistage process to design, pretest, and implement the survey to water system managers in the four states following a standard methodology (Dillman, Smith, and Christian, 2008). A literature review, interviews with water managers, and discussions with survey experts informed our survey design. The survey was pretested on a subsample of 88 water system managers using an online survey, which solicited feedback on each question. After modifying the survey to reflect pretest feedback, the final version of the survey contained 33 questions. The pretest also confirmed that online delivery would be an appropriate way to distribute the surveys (Boyer, Adams, and Lucero, 2010).

We identified publicly available contact information for 1834 community water systems (those with at least 50 connections) in the four states. Water systems were contacted initially by phone, and water managers or their equivalent were asked whether they would be willing to take the survey and whether they would prefer the web-based or hard-copy version. Contact information for 149 water systems was invalid, reducing our list to 1685 water systems.

We implemented the survey from June to December 2009. Water managers preferring the web-based version were sent 1) an introductory e-mail to notify them that the survey was forthcoming and to validate the e-mail addresses; 2) a cover letter with a secure link to the survey; and 3) two follow-up e-mails to nonrespondents (Dillman, Smith, and Christian, 2008). Those preferring the hard copy were provided similar materials via USPS mail. Each water system in our sample received a presurvey notification, survey with a cover letter, a thank you letter, and reminder materials as needed.

To determine if water system characteristics, managers' attitudes and perceptions toward water conservation, and future planning strategies

influence the adoption of PC and NPC programs, we evaluated responses from several specific questions about these factors. Water systems provided information on the location of the water system, the average quantity of water delivered per day, the primary water source (e.g., groundwater or surface water), if it had a secondary water supply, if it purchased or owned its water supply, the water system's organization structure (e.g., municipal, cooperative, rural water authority), and how its end-users' water demand has changed in the last five years from the time the survey was completed. These questions were used to describe the water system characteristics. The water managers' attitudes and perceptions toward water conservation were observed by asking about the impact of climate change on water supplies, the water system experience measuring how changing the price of water impacts end-users' water use, expectation of changes in water use if the price of water is increased 10%, and perceived barriers to adopting PC and NPC programs. Finally, we asked water system managers about plans for meeting future water demand and what factors they expected to significantly impact the water system's ability to meet future water demand.

Table 2 provides a full description of the dependent and independent variables in the model as well as the average values of the raw survey data used. As suggested by the mean values presented in Table 2, several surveys were incomplete. Rather than drop observations with incomplete answers to one or more questions, which would have substantially reduced the number of useable observations, we imputed missing values using multiple imputation (Kyureghian, Capps, and Nayga, 2011; Rubin, 1987; Schafer, 1999). Multiple imputation replaces missing responses with values predicted from other responses, which are a plausible set of values that represent the uncertainty about the correct value to impute (Rubin, 1987). We use the MI and MIANALYZE procedures in SAS (SAS Institute Inc., 2004) using a Markov Chain Monte Carlo algorithm to simulate the posterior distribution and to create pseudorandom draws from the probability distribution. This is a common and robust approach to deal with

Table 2. Description and Average Values of Variables in the Predictive Models

Variable	Description of Independent Variables	Mean[c]	Imputed Means
Dependent Variables			
PC[a]	Adopted inclining block rate or increased uniform rate sometime in the last five years	0.19	0.19
NPC[a]	Adopted a NPC program sometime in the last five years	0.24	0.24
Water System Characteristics			
Florida	Water system is located in Florida	0.22	0.22
Oklahoma	Water system is located in Oklahoma	0.40	0.40
Arkansas	Water system is located in Arkansas	0.23	0.23
Tennessee	Water system is located in Tennessee	0.15	0.15
Small	Delivers less than 0.5 million gallons per day (MGD) of drinking water	0.50	0.50
Medium	Delivers between 0.5 and 2.0 MGD of drinking water	0.25	0.25
Large	Delivers more than 2.0 MGD of drinking water	0.25	0.25
GW	Primary source of water is groundwater	0.48	0.52
SW	Primary source of water is surface water	0.45	0.48
PurW	Purchases primary source of water (does not own water supply)	0.28	0.28
SecW	Has a secondary source of water available	0.07	0.07
Muni	The water system is owned by the city	0.62	0.63
Coop	The water system is owned by the end-users	0.22	0.25
RWA	Rural water authority might include several small communities	0.02	0.02
Private	Private investor owned facility	0.01	0.01
OtherStr	Other public organization structure	0.08	0.09
PCdec[a]	Per-capita water use by end-users has decreased in the last five years	0.12	0.16
PCsame[a]	Per-capita water use by end-users has stayed constant in the last five years	0.43	0.55
PCinc[a]	Per-capita water use by end-users has increased in the last five years	0.23	0.29
Attitudes and Perceptions			
CCn	Does not believe climate change will impact water supplies	0.29	0.32
CCy	Believes climate change will impact water supplies	0.23	0.25
CCns	Not sure if climate change will impact water supplies	0.38	0.43
PRy-Guess	Has measured how price changes impact water use by guessing	0.02	0.02
PRy-IntS	Has measured how price changes impact water use by an internal study	0.06	0.07
PRy-ExtS	Has measured how price changes impact water use by an external study	0.03	0.03
PRn	Has not measured how price changes impact water use	0.44	0.53
PRns	Not sure if measured how price changes impact water use	0.27	0.34
NoChg	A 10% increase in water price will not change water use	0.50	0.60
Dec	A 10% increase in water price will decrease water use	0.30	0.35
Inc	A 10% increase in water price will increase water use	0.05	0.05
BarNoNeed[b]	Barrier to adopt PC/NPC is no need to conserve water	0.51	0.51
BarCE[b]	Barrier to adopt PC/NPC is the cost effectiveness of the programs	0.17	0.17
BarPol[b]	Barrier to adopt PC/NPC is the political pressure	0.13	0.13

Table 2. Continued

Variable	Description of Independent Variables	Mean[c]	Imputed Means
Future Planning			
AltS[b]	Plans to use an alternative source to meet future demand	0.10	0.10
Inf[b]	Plans to replace/expand existing infrastructure to meet future demand	0.57	0.57
Waste[b]	Inefficient water use by end-users will impact ability to meet future water needs	0.37	0.37
TrtC[b]	Increasing treatment costs will impact ability to meet future water needs	0.42	0.42
WdL[b]	Inability to maintain withdrawal levels will impact ability to meet future water needs	0.11	0.11
Pop[b]	Population growth will impact ability to meet future water needs	0.45	0.45
Regs[b]	Increasing cost to meet testing and other regulatory requirements	0.52	0.52

[a] The five-year period is referenced from the time the survey is completed by the respondent.
[b] This question allowed respondents to select all that apply.
[c] Variables are binary with calculated values between 0 and 1. Some categories sum to less than 1 as a result of incomplete observations.
PC, price-based conservation; NPC, nonprice-based conservation.

incomplete survey responses (Kyureghian, Capps, and Nayga, 2011; Schunk, 2008). Mathematically, this procedure first estimates a posterior distribution of the parameter values as:

$$(7) \quad f(\theta|X_{obs}) = \int_{X_m} f(\theta|X_{obs},X_m)f(X_m|X_{obs})dX_{obs}$$

where X_m are the missing observations, X_{obs} are the observed observations, θ is a set of parameter values to be estimated, $f(X_m|X_{obs})$ is the predictive density of the missing observations given the observed observations, and $f(\theta|X_{obs},X_m)$ is the conditional density of θ given the complete data set. The predictive density of the missing observations given the observed observations is:

$$(8) \quad f(X_m|X_{obs}) = \int_{\Theta} f(X_{obs}|\phi,X_{obs})f(\iota|X_{obs})d\phi$$

where Θ is the parameter space of θ. The parameters of the posterior distribution are estimated, and the value can be drawn from the predictive distribution, which is:

$$(9) \quad X_m^* \sim P(X_m|X_{obs},\theta^*)$$

where X_m^* are the replacement values and θ^* are the parameter estimates. See Schunk (2008) for

a detailed mathematical explanation of this process. Table 2 reports the imputed mean value for each variable.

Results

Survey Response

We received 695 responses for a 41% response rate, which is considered high for mixed-mode surveys (Dillman, Smith, and Christian, 2008) and compares very favorably with other water system surveys (e.g., Dickinson, Maddaus, and Maddaus, 2003). Five hundred ninety-four of the responses were by the web-based survey and 101 responses were by the hard-copy survey. Specifically, we received 292 responses from Oklahoma (OK) utilities for a response rate of 49%, 155 from Florida (FL) for a response rate of 48%, 149 from Arkansas (AR) for a response rate of 41%, and 99 from Tennessee (TN) for a response rate of 20%. These responses provide a sampling error less than ±2.85% at the 95% confidence level. We tested for nonresponse bias (e.g., Armstrong and Overton, 1977) and coverage bias (e.g., Boyer, Adams, and Lucero, 2010) but found no serious problems.

We show the adoption of PC, NPC, both PC and NPC, and no adoption by state and water system size (Figures 1 and 2). More FL water systems adopted PC and NPC programs than any other state in the last five years, and AR had the lowest percentage of water systems adopting PC and NPC programs (Figure 1). OK water systems adopted more PC than NPC programs, whereas AR, TN, and FL adopted more NPC programs than PC programs (Figure 1) within the last five years from the time the survey was completed. More large water systems than small- or medium-sized systems adopted NPC and PC (Figure 2).

Statistical Models

We parameterized econometric models in SAS using the QLIM procedure for the bivariate probit model (Equation [6]) and SURVEYLO-GISTIC procedure for the two probit models (Equations [4] and [5]) (SAS Institute Inc., 2004). The bivariate probit model fits the data well, but the variable $\rho = -0.003$, which captures the relationship between PC and NPC choices, is not statistically different from zero ($p = 0.7954$). This means that water systems in our sample generally do not make PC and NPC adoption decisions jointly (Greene, 2008); thus, the separate probit models for PC and NPC adoption are more appropriate models.

We report parameter estimates from the probit models in Table 3. For each question that is not a "select all that apply" question, one of the response categories is dropped to avoid multicollinearity issues. The sign of each parameter estimate indicates the effect the independent variable has on the probability of PC and NPC adoption, respectively, relative to the omitted category and holding all other independent variables constant. A positive (negative) parameter estimate indicates that the variable increases (decreases) the likelihood of adopting the water conservation program. For PC adoption, the model correctly predicts 77.26% of the dependent variables, has a McFadden R^2 value of 0.2210, and has a likelihood ratio p value < 0.001. The NPC adoption model has a percent correctly predicted of 80.14%, a McFadden R^2 value of 0.34, and a likelihood ratio p value < 0.001.

Price-based Conservation Adoption

Water systems in FL and OK are more likely to adopt a PC program relative to systems in AR. This may indicate inherent differences between states, perhaps as a result of state-level programs, population growth, water endowments, or other factors that influence the adoption of PC by state. A water system's reliance on
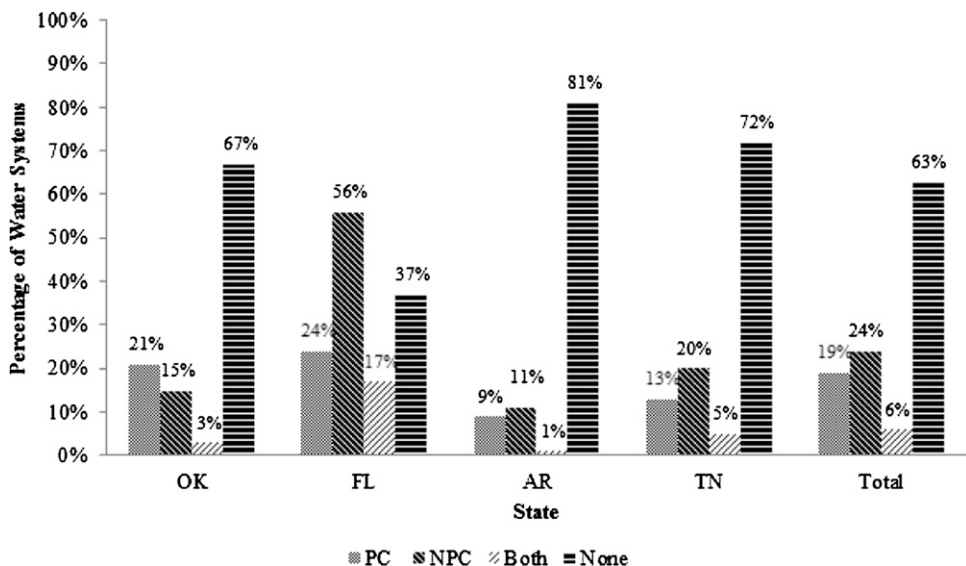
Figure 1. Water Conservation Adoption within Five Years of Survey Completion, by State
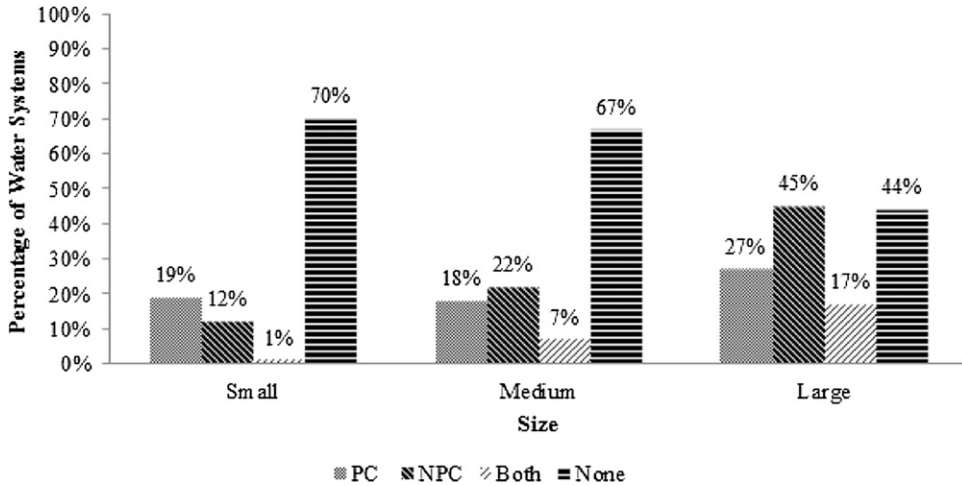
Figure 2.   Water Conservation Adoption within Five Years of Survey Completion, by Utility Size

groundwater is not found to influence the adoption of PC programs. This is consistent with Teodoro's (2009) finding that the source of water does not impact the adoption of an inclining block rate pricing structure. However, we found that if a water system does not own its water supply, but has to purchase its primary source of water, the water system is more likely to adopt PC. Several variables that describe a water system manager's attitudes and perceptions toward water conservation programs also impact PC adoption. If a water system manager believes that climate change will not impact his or her system's water supply, the water system is less likely to adopt PC relative to a manager that is not sure about the impact of climate change on water supply. If a water system has measured price elasticity of water demand by best guess or conducting an internal study, the likelihood that a water system will adopt PC increases relative to a water system that has not measured price elasticity of water demand. A water system manager who is unsure if the price elasticity of water demand has been measured for his or her water system is less likely to adopt PC. Finally, if a manager believes that increasing the price of water will not change end-users' water use, his or her water system is less likely to adopt PC. Essentially, this means that if a manager views PC as ineffective at conserving water, his or her system will likely not adopt PC. Water systems planning on meeting future water demands by

investing in infrastructure replacement or expansion are more likely to adopt PC. Those planning on using "alternative" water sources such as gray water reuse or desalination are more likely to adopt PC. Finally, water systems confronted with population growth are more likely to adopt PC.

Nonprice-based Conservation Adoption

Our results indicate that water system characteristics also influence NPC adoption. FL water systems were more likely to adopt NPC relative to AR water systems, but parameter estimates for OK and TN were insignificant. Although water system size is insignificant in adopting PC, size does drive NPC adoption with large water systems being more likely to adopt NPC. Having measured the impact of price changes on end-user water demand increases the likelihood of adopting NPC as it does with PC. However, unlike PC, having conducted external studies increases the likelihood of NPC adoption, whereas using an internal study and/or best guess approach is insignificant. Planning on using alternative water sources (e.g., gray water reuse or desalination) and believing that inability to maintain withdrawal levels of current water supplies will impact their ability to meet future water demand both increase the likelihood of NPC adoption. These findings may indicate that water systems in our study

Table 3. Estimates from the Probit Models for Factors Influencing Price and Nonprice Conservation Adoption

	Dependent Variables			
	Price-based Conservation		Nonprice Conservation	
Independent Variable	Coefficient	*p* Value	Coefficient	*p* Value
Water System Characteristics				
Florida	0.553**	0.0322	0.833***	0.0002
Oklahoma	0.582***	0.0021	0.293	0.1298
Tennessee	0.247	0.2994	0.247	0.2713
Medium	−0.166	0.4198	0.317	0.1259
Large	0.100	0.6364	0.518**	0.0208
GW	0.205	0.1974	0.148	0.3775
PurW	0.274*	0.0888	0.181	0.2805
SecW	−0.217	0.4328	−0.034	0.8877
Muni	0.363	0.3985	0.269	0.4896
Coop	0.294	0.5208	0.052	0.9038
RWA	−0.213	0.6522	0.030	0.9551
OtherStr	0.625	0.1615	0.410	0.3390
PCdec	0.239	0.1261	0.279	0.1684
PCinc	0.230	0.2860	−0.122	0.4962
Attitudes and Perceptions				
CCn	−0.296*	0.0644	−0.189	0.2593
CCy	0.017	0.9097	0.072	0.6580
PRy-Guess	0.765**	0.0307	0.562	0.1612
PRy-IntS	0.417*	0.0934	−0.105	0.6854
PRy-ExtS	0.197	0.5741	0.748**	0.0352
PRns	−0.277**	0.0428	−0.171	0.2258
NoChg	−0.528*	0.0541	−0.336	0.2717
Dec	−0.225	0.4224	−0.255	0.4205
BarNoNeed[a]	0.025	0.8524	−0.191	0.1265
BarPol[a]	−0.048	0.8201	0.175	0.3845
BarCE[a]	−0.149	0.4013	−0.146	0.3779
Future Planning				
AltS[a]	0.404*	0.0709	0.582***	0.0079
Inf[a]	0.402***	0.0040	−0.007	0.9564
Waste[a]	0.024	0.8598	−0.030	0.8250
TrtC[a]	0.233	0.1259	−0.018	0.9052
WdL[a]	−0.158	0.4307	0.462**	0.0140
Pop[a]	0.271**	0.0401	−0.052	0.6785
Regs[a]	0.121	0.5941	−0.065	0.6094

*Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

[a] This question allowed respondents to select all that apply.

are highly motivated to conserve water as a result of significant water supply constraints.

Discussion

Kenney et al. (2008) and Renwick and Archibald (1998) suggest that NPC and/or PC can be made jointly by a water system, but we find no evidence from the bivariate probit model to support this hypothesis. Thus, our discussion focuses on parameter estimates from separate PC and NPC probit models.

We can draw many interesting implications from the results for PC and NPC adoption models. For PC adoption, we find that water system managers who believe climate change

will not impact their system's water supply are less likely to adopt PC. This is an intuitive result given that climate change is expected to increase the occurrence of extreme weather events that will stress existing water resources and infrastructure. Additionally, many water system managers commented in the survey about the uncertainty of climate change effects on water supplies, suggesting that this is an area of interest for water system managers and is worthy of additional investigation by future studies. Measuring the price elasticity of water demand increases the likelihood that a water system will adopt PC. Knowing the price elasticity of end-users' water demand may allow a water system to better understand the impacts of price changes on water use, which can reduce uncertainty about the impacts of water price changes on revenue streams. The results also suggest that water systems with little understanding of how water end-users respond to price changes are less likely to adopt PC. Therefore, the results suggest that when managers know that end-users respond to increases in the price of water, water systems are more likely to use PC, whereas managers who are not aware that end-users respond to price increases in water are less likely to report PC adoption. This result confirms that information about the price elasticity of water demand for a community matters in PC adoption. Water systems planning on using "alternative" water sources and replacing/expanding existing infrastructure to meet future demand are more likely to adopt PC. This seems like an intuitive result given the typical costs of supply expansion projects relative to increasing the efficiency of water infrastructure. By adopting PC, these water systems might be able to avoid the necessary next step in meeting future water demand of supply expansion projects.

The likelihood of adopting NPC programs increases when a water system is large (i.e., delivers more than 2.0 million gallons per day). NPC programs can be expensive (e.g., rebates on low-flow devices) and labor-intensive (e.g., awareness/education), perhaps making it difficult for small water systems to adopt NPC programs. Florida has a longer history of water supply issues than the other states included in

this survey, which might explain why FL is the most likely to adopt NPC. Measuring the impact of price changes on end-users' water demand also increases the likelihood of adopting NPC, but unlike PC adoption, water systems that have performed an external study on the price elasticity of water demand are more likely to adopt NPC. We expect that water systems that can afford to pay for an external study are more likely to have the capital resources also needed to implement NPC. This might explain why larger water systems are more likely to adopt NPC as well as pay for an external study of end-users' water demand. These findings further emphasize the important role that demand information plays in PC and NPC adoption. Water systems preparing to use alternative water sources to meet future water demand and who are concerned about the inability to maintain withdrawal levels in the future are more likely to adopt NPC. A possible explanation might be these water systems are confronting significant water supply constraints and are trying to increase water use efficiency of its current water supply with various NPC programs.

Additionally, several variables that were anticipated to be significant factors in PC and NPC adoption were not significant. For example, organizational structure of a water system did not impact the influence of PC and NPC adoption, which is a departure from Hearne and Kritsky (2010) and Teodoro (2009). There were no statistically significant barriers to adopting PC and NPC, which merits attention from future surveys. The perception that there is no need to conserve water was an insignificant factor in PC and NPC adoption, which may imply that water resources are not yet viewed as becoming seriously limited in most parts of this region. However, significant factors such as planning on using alternative water sources in the future could provide evidence that water resources are becoming more limiting in the southern United States. Further research is needed into this discrepancy.

Moving forward, many states in the southern United States have recognized the need to develop strong state policies to better manage water resources for the future (e.g., Mullen,

2011). For example, Oklahoma is currently updating its 50-year comprehensive water plan, and Georgia is completing its statewide comprehensive water plan, which involves using both PC and NPC programs to manage water resources (Mullen, 2011). Properly balancing water conservation programs and supply expansion projects may be vital to developing an effective long-term water management plan (Maddaus, Gleason, and Darmody, 1996). Results of our models highlight several important factors that influence the adoption of PC and NPC programs, and the findings can be used by state agencies and others in the southern United States to inform demand management as a possible tool to meet future water needs. For example, we know that providing water systems with tools to internally measure end-users' price elasticity of water demand could encourage PC adoption where appropriate.

Conclusions

The objective of this article is to assess water system characteristics, managers' attitudes and perceptions toward water conservation, and future planning strategies that may influence the adoption of PC and NPC programs. We surveyed water system managers in Arkansas, Florida, Oklahoma, and Tennessee to determine how water system characteristics, managers' attitudes and perceptions toward water conservation, and future planning strategies influence the use of water conservation programs. Importantly, we included a range of water systems from large, urban communities to small, rural areas.

We found a number of statistically significant drivers of water conservation, and our results contribute to the growing literature on drivers of water conservation programs. Unlike most prior studies (Boyer et al., 2012, is a noted exception), we considered a large number of water systems from a broad geographic region (four states) rather than a specific location (e.g., Kenney et al., 2008; Kenney, Klein, and Clark, 2004), and we specifically included rural communities rather than focusing only on large urban areas (e.g., Michelsen, McGuckin, and Stumpf, 1999). Furthermore, previous research

has only partially addressed factors that drive PC adoption (Boyer et al., 2012; Hearne and Kritsky, 2010; Teodoro, 2009), but we reach beyond the previous research by identifying factors that drive NPC adoption. We note that Boyer et al. (2012) also examined the influence of water system size, primary water source, and the state where the water system is located on adoption of inclining block rates versus uniform rates; however, we examine a number of explanatory variables not addressed by that study, apply very different econometric modeling specifications, and define PC differently. Finally, agricultural water conservation has been the primary focus of the water conservation research in the southern United States (Ding and Peterson, 2012; Johnson et al., 2011; Jordan, 2008; Rister et al., 2011; Wheeler et al., 2008), and aside from this study, little is known about the adoption of urban and rural water conservation programs in southern US communities.

We note several potential limitations of our study. Given the strong tradeoff between survey length and response rates, we limited our attention to questions related to water managers and system characteristics. A minority of the explanatory variables that we did include were statistically significant (11 in the PC model; five in the NPC). Community demographics such as population, income, age, and education may also be important drivers of PC and NPC adoption, but we did not collect these data. Also, we did not directly capture water managers' views on risk or the role of water quality regulations (e.g., sewer and effluent release), which may influence conservation adoption. Additionally, we recognize that not all water conservation strategies may do a good job balancing goals of water use efficiency, revenue sufficiency, and revenue stability. Finally, program cost, labor requirements, implementation complexity, and uncertainty of success may vary significantly by PC and NPC tool. Although we grouped various available water conservation tools into only two categories (price- and nonprice-based conservation), a more nuanced view may be warranted when evaluating conservation adoption. Finally, we were interested in recent adoption of NPC and PC, and limited our focus to changes in water rate structures in

the last five years, which could have excluded early adopters. Future work might examine the dynamics of PC and NPC adoption over time and for a much longer timeframe.

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