Received: 22 October 2018 | Revised: 12 February 2019 | Accepted: 13 February 2019

DOI: 10.1002/aws2.1132

AWWA WATER SCIENCE

ORIGINAL RESEARCH

Introducing a new measure of residential water rate progressivity

David Switzer

Truman School of Public Affairs, University of Missouri, Columbia, Missouri

Correspondence
David Switzer, Truman School of Public Affairs, University of Missouri, 232 Middlebush Hall, Columbia, MO 65211.
Email: switzerd@missouri.edu

Utility rate structures play a crucial role in water conservation. Rate structures send signals to consumers about the desired level of water consumption. Despite the importance of rates as a form of conservation policy, there is currently no broadly comparable measure of the conservation orientation of utility rate structures across rate structure types. Previous studies investigating the correlates of rate structures have made use of a dichotomous variable of whether a utility has adopted conservation-oriented rates. I develop a slope-based measure of rate progressivity to capture the variation of water rates. Using an original data set of utility rates data for 852 U.S. cities, I explore the distribution and variety of water rates across the United States and use a statistical analysis to explore the potential correlates of municipal rate progressivity, showing differences between the dichotomous and continuous measures.

KEYWORDS

conservation, utility policy, water rates

1 | INTRODUCTION

As the population of the United States has more than doubled since 1950 and shifted from rural to urban areas, water supplies in many areas have become strained (Kenny et al., 2009). Water utilities are facing increasing challenges of scarcity, and the looming threat of climate change will only exacerbate this issue in the future (Levin et al., 2002). These changing conditions can be seen most starkly in the recent California drought, which was the most severe drought in California in the previous 1,200 years (Griffin & Anchukaitis, 2014). Adapting to the changing realities of water conservation means understanding the policy choices facing utilities, and the choice of a water rate structure plays an integral role in water conservation. Adopting a rate structure that charges high-volume users a higher marginal price for consumption, also known as an increasing block or progressive rate structure, is one of the simplest ways utilities can encourage conservation among citizens (Teodoro, 2010; Whitcomb, 2005). On the other hand, adopting a rate structure that charges high-volume users the same or even a lower marginal cost for consumption may send a minimal conservation signal.

Despite the importance of rates as a form of conservation policy, there is currently no broadly comparable measure of the conservation orientation of utility residential rate structures, which provides a limit to the inferences that can be made about local water conservation policy, at least when it comes to water rates. To this point, quantitative studies investigating the correlates of conservation rate structures have made use of a dichotomous variable of whether a utility has adopted a rate structure traditionally considered conservation oriented (Aubuchon & Roberson, 2012; Mullin, 2008; Teodoro, 2010). While this approach has its merits, I argue that it may be advantageous to consider a continuous measure of water rates that looks at the escalation of prices as progressive/regressive, similarly to how tax rates can be considered progressive or regressive. This approach allows for a deeper understanding of the rich variety of rate structure choices available to utilities. Importantly, even within those rates traditionally considered conservation oriented, there is a great deal of variation in how marginal prices increase as consumption goes up, which ultimately determines how strong a conservation signal the rate structure is sending (Whitcomb, 2005).

In this article, I argue for and develop a continuous measure of rate progressivity across residential rate structure types. I begin by showing why such a measure is useful, using the rates of the cities of Fullerton, California, and Annapolis, Maryland, as motivating examples. I develop a new measure of rate progressivity using a slope-based measure that shows how increasing consumption results in changes in the price charged per unit of water. I use the water rates of Durham, North Carolina, and Des Moines, Iowa, to show how the measure is developed. Then, using an original data set of utility rate data for 852 U.S. cities with more than 20,000 people, I explore the distribution and variety of water rates across the United States and use a econometric analysis to explore the potential correlates of municipal rate progressivity, investigating the influence of political ideology, water scarcity, population constraints, and demographic characteristics on water rates. I compare the results to a model that uses a dichotomous measure of rate structure choice, finding that the new measure of rate progressivity can change inferences about water conservation policy in the United States.

2 | TYPES OF WATER RATES

Before developing a new measure of rate progressivity, it is important to first understand the basic typology of water rate structures. There are many varieties of rate structures, but they can most easily be grouped into five basic types (Teodoro, 2010):

- *Flat rates*: This rate structure charges all customers the same price for a fixed time period, regardless of the amount of water consumed. This rate structure does not require metering and is therefore less costly from an administrative perspective.
- *Uniform rates*: This rate structure charges all customers the same price per unit of water, regardless of the amount of water consumed.
- *Decreasing block rates*: This rate structure charges higher prices per unit for low-volume users than for high-volume users. As water consumption increases, price per unit decreases. The rate structure is broken up into consumption blocks, where per-unit charges are determined based on whether water consumption has exceeded a certain level.
- *Increasing block rates*: Also known as a progressive rate, this rate structure charges higher prices per unit for high-volume users than for low-volume users. As water consumption increases, price per unit increases. Similar to decreasing block rates, the price per unit is determined by which block of consumption the user is in.
- *Seasonal rates:* This rate structure charges higher prices per unit in periods of high demand or low supply and lower prices per unit in periods of low demand or high supply. The price per unit depends on when the consumption is taking place during the year. Seasonal rates can be mixed with any other kind of rate structure.

Although any rate structure that has a marginal price above zero can be considered to be encouraging water conservation, studies have usually focused on seasonal and increasing block rates as being conservation oriented (Lippiatt & Weber, 1982; Mullin, 2008; Teodoro, 2010). Increasing block rates are considered to be especially conservation oriented, specifically because they charge higher-volume users higher prices per unit of water consumed. Increasing block rates send a signal to customers to decrease consumption by increasing the differential between their marginal cost and average cost (Whitcomb, 2005). Crucially, for most utilities, mean customer water consumption is higher than median consumption due to the presence of a few extremely high water users (Chestnutt et al., 1997). This means that the median customer should usually benefit from an increasing block rate structure as high-consumption customers will bear the burden of the increased price per unit for consumption in the higher blocks, and it is ultimately the very high-volume users who are targeted by increasing block rates (Teodoro, 2010). Under increasing block rate structures, the only way for high-volume users to avoid the higher per-unit costs associated with higher blocks is to conserve water.

Not all increasing block rate structures, however, are created equal. Much like tax rates differ in terms of how progressive they are, taxing higher or lower percentages depending on income level, water rate structures differ in their levels of progressivity, with some charging significantly higher marginal prices in higher blocks, while others only charge slightly more for higher-volume use. The severity of the increase in price for higher volume sends a signal to customers. Rates with higher marginal costs for high-volume users are more likely to cause increased conservation, while only a slight increase in marginal costs for high-volume users may not send much of a conservation signal at all.

Rate structures matter for conservation. While there is some debate over the price elasticity of water, there is no question that the aggregate effects of price changes can be quite large (Campbell, Johnson, & Larson, 2004). Campbell et al. (2004), for example, estimated that the price elasticity of demand for water in Phoenix was −0.27, meaning a 1% increase in price would lead to a 0.27% decrease in consumption. Despite the relatively low elasticity, however, they estimated that a 10% price increase could lead to a reduction of over 1 billion gallons of water a year as the price increase would apply to such a large number of users. In addition, while there is some evidence that elasticity decreases for the highest-income users, prices affect conservation behaviors across all income groups (Whitcomb, 2005).

3 | MEASURING RATE STRUCTURE PROGRESSIVITY

In what studies there have been on water utility rate structures nationally, the measurement of water rate structures has traditionally, and quite reasonably, focused on a dichotomous approach, exploring whether a utility uses seasonal/increasing block rates or not (Mullin, 2008; Teodoro, 2010). Certainly, the utility's decision to choose a rate that charges higher amounts during high-demand periods or for larger-volume users reflect the values of the decision makers. In addition, the complicated nature of water rates means that data collection may be quite difficult at a large scale. Previous studies have relied primarily on surveys, which may not go into detail when it comes to full information about utility rates (Mullin, 2008; Teodoro, 2010).

Still, while this strategy is reasonable for understanding the general commitment of utilities to conservation, this approach is limited by its dichotomous nature. Only exploring the type of rate structure, and not exploring the immense variation within rate structures, potentially limits the inferences that can be made about utility conservation policy. Ultimately, considering rate structures a dichotomous choice collapses what is really a continuous variable. There is rich variation among rate structures that would be considered conservation oriented.

An example will show why the dichotomous approach may not be sufficient for capturing rate progressivity and therefore not fully reflect the conservation commitment of water utilities. Consider two cities on opposite coasts: Fullerton, California, and Annapolis, Maryland. The water rates charged by the two utilities are displayed in Table 1. Both utilities use increasing block rate structures that contain three consumption blocks with the cut-off points at the same usage. A dichotomous approach to these two cities would identify these rate structures as identical. The prices charged per 1,000 gal within those blocks, however, suggest that measuring these two cities as having identical rate structures, as the dichotomous approach would, may be problematic. While the price charged per 1,000 gal in the first block is relatively similar across both cities, Annapolis escalates the price much more, charging over three times as much per 1,000 gal in the third block as the first, while Fullerton only charges 59 cents more per 1,000 gal.[1]

Because what sends a conservation signal to customers is the difference between the marginal price and average price of water, Annapolis' rate structure is far more conservation oriented than Fullerton's (Whitcomb, 2005). While using an increasing block rate structure, the lack of escalation in the Fullerton's blocks means the city's high-volume users do not face a strong incentive to decrease usage. In

TABLE 1 Comparing two increasing block rate structures

	Fullerton	Annapolis
Increasing block rate?	Yes	Yes
Number of blocks	3	3
Cut-off point 1 (gal)	7,000	7,000
Cut-off point 2 (gal)	20,000	20,000
First block price (per 1,000 gal)	$3.12	$3.37
Second block price (per 1,000 gal)	$3.42	$6.76
Third block price (per 1,000 gal)	$3.71	$10.12

Annapolis, the sharp escalation of prices in higher blocks of consumption is a strong incentive for conservation. Treating these rates the same could potentially lead to incorrect inferences about local water policy decisions, as there are likely far different political, administrative, and environmental incentives that lead to the adoption of a highly accelerating increasing block rate structure and a slowly accelerating structure. Adoption of a conservation rate structure could be indicative of a symbolic commitment without much cost to consumers or the utility. A seasonal or increasing block rate with little increase in marginal price is a nominal commitment but not one that is likely to be costly for customers or have much influence on conservation behavior. A steeply increasing marginal price, however, could risk backlash from customers.

An additional issue exists with respect to declining block rates. Previous studies have not considered the differences between the nonconservation-oriented rate structures. Instead, they have lumped flat, uniform, and decreasing block rates together (Aubuchon & Roberson, 2012; Mullin, 2008; Teodoro, 2010). While none of these rate structures are considered conservation oriented, decreasing block rates have different implications for water conservation than do uniform or flat rates. Decreasing block rates do little to incentivize lower rates of consumption by charging less per unit of water in higher-consumption blocks. There exists great variation among decreasing block rates as well. While some only charge lower rates once consumption is extremely high, such as Rochester, New York, which only starts charging lower rates after consumption has reached 300,000 gal in a month, almost certainly meant to benefit commercial or industrial use, other utilities begin charging lower prices even at low levels of consumption that would affect residential usage as well. Kansas City, Kansas, charges lower prices per 1,000 gal after only 5,000 gal of water consumed in a month. Further compounding this issue is that some rate structures include elements of both increasing and declining block structures. They begin by charging higher rates as consumption increases, but after a certain point, they start charging lower rates. It is difficult to determine how to operationalize these rate structures in a dichotomous measure.

4 | A NEW MEASURE OF WATER RATE PROGRESSIVITY

To this point, I have identified a number of issues with using dichotomous measures of water rates to quantify utility conservation policy. What remains is to find a better way. As there is no previous study that has identified a continuous variable measuring water rate progressivity, a new one needs to be developed. I introduce a new measure of water rate progressivity that allows for a comparison of the conservation orientation of utility water rates. Essentially, the measure calculates the slope of a regression line through the average price per 1,000 gal for each of the first 13,000-gal blocks of consumption. It measures the average rate at which price per 1,000 gal changes in increments of 1,000 gal up to 13,000 gal. The choice of 13,000 gal is not arbitrary but rather reflects what DeOreo, Mayer, Dziegielewski, and Kiefer (2016) found was two standard deviation (*SD*s) above mean residential consumption in their study of 23,749 households in 23 utilities. I calculated the price per 1,000 gal for each of the first 13,000-gal blocks. I then regress the price per 1,000 gal on the number of 1,000 gal consumed, with the consumption block number as the X value and the average price per 1,000 gal at the specific level of consumption as the Y value. The data that go into the regression for each utility have the following characteristics:

> $X = (1, 2, 3, \ldots, 13)$, where each value represents the consumption block. $X = 1$ represents the block from 0 to 1,000 gal of consumption, $X = 2$ represents the block from 1,000 to 2,000 gal, and so on.
>
> Y = ($/1,000 gal from 0 to 1,000 gal, $/1,000 gal from 1,000 to 2,000, $/1,000 gal from 2,000 to 3,000 … $/1,000 gal from 12,000 to 13,000), where each value represents the average price per 1,000 gal for each consumption block.[2]

After collecting these data for a given utility, I use least squares regression to calculate the slope of a line going through the data. The slope of this line is the measure of water rate progressivity:

$$\text{Rate progressivity} = \frac{\Sigma_{i=1}^{13}(x_i - \bar{X})(y_i - \bar{Y})}{\Sigma_{i=1}^{13}(x_i - \bar{X})^2}$$

Put another way, the measure is the average change in price per 1,000 gal moving up a 1,000-gal consumption block. A positive slope means that higher-consumption users are paying more per unit of water, while a negative slope means higher-consumption users actually pay less per unit of water. A slope of 0 means that consumption has no effect on the price per unit of water, which is the case for flat and uniform rates. The process by which this measure is created can be seen in Figure 1, where the procedure is graphed for

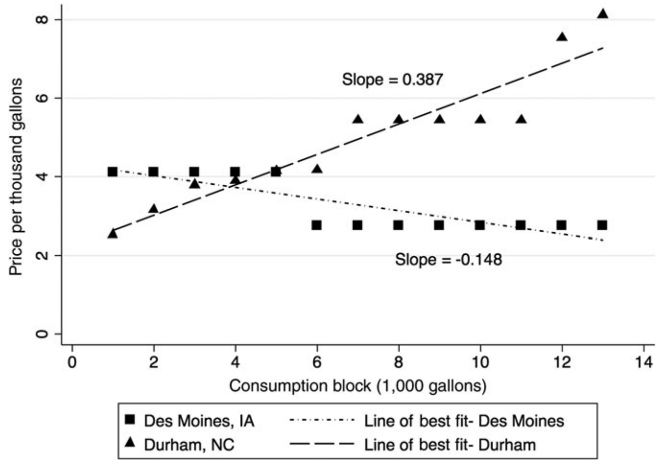

FIGURE 1 Calculating rate progressivity for Des Moines and Durham

the utility rates in Des Moines, Iowa, and Durham, North Carolina. Des Moines has one of the more regressive water rate structures in the data set with a slope of −0.148. This means that moving up a 1,000-gal block of consumption is, on average, associated with a corresponding $0.15 decrease in price paid per 1,000 gal. Durham, on the other hand, has one of the most progressive rate structures in the data set with an increase in 1,000-gal block associated with a $0.39 average increase in the amount charged per 1,000 gal.

To show how this changes our understanding from a dichotomous approach, we need only consider once more the case of Fullerton and Annapolis. Under prior measurement systems, their rate structures would have been considered identical; the new measure of progressivity demonstrates how different they actually are. The slope for Fullerton's rate structure is 0.033, while the slope for Annapolis is 0.391. Despite their same rate structure typology, same number of blocks, and same ranges of consumption within blocks, the progressivity of Annapolis' rate structure is over 10 times Fullerton's according to this new measure.

A few caveats about this measure should be noted here. First, while this measure captures far more variation than a dichotomous measure, it does make a strong assumption of linearity. Rates increase in block form rather than linearly, so the measure does not perfectly capture all of the variation among rates. In general, this measure is one approach that captures the progressivity of rate structures for broad comparisons. Other new measures may be developed that could be more appropriate in other contexts. In addition, although it is grounded in the findings of DeOreo et al. (2016), the cut-off point of 13,000 gal may be flexible depending on the region under study. Average water use varies greatly across regions, and researchers and analysts should use their own discretion and knowledge in deciding what the appropriate cut-off point is for their question. Finally, I do not intend for this to be the final word on rate progressivity but rather consider it a start of a broader conversation about the appropriate ways to measure water rate structures. With the sharing

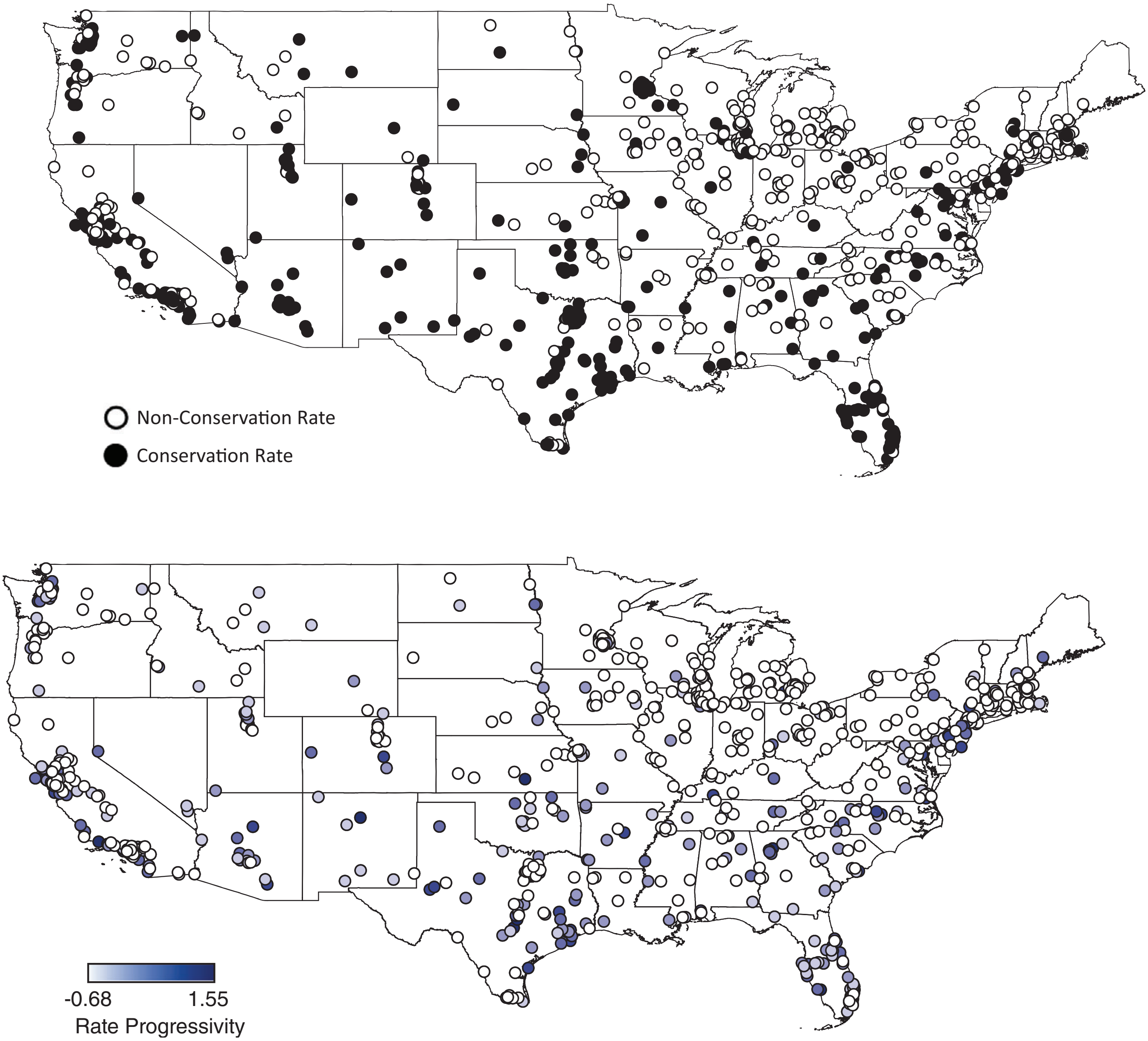

FIGURE 2 Map of water rates in the contiguous United States

of water rates on government websites, there is more information available than ever for researchers to explore the variation among water rates.

5 | RATE PROGRESSIVITY IN THE UNITED STATES

Now that a new measure of water rate progressivity has been developed, it is possible to better understand the nature of water rate structure progressivity across the United States. To do this, I collected water rates data from city websites for 852 cities with populations of greater than 20,000.[3] This data set contains water rate information for almost all cities of this size that run their own utility.

To begin, we can look at how many utilities throughout the country use seasonal or increasing block rates, which signals a commitment to conservation, as those rate structures are traditionally considered conservation oriented. A total of 53% of the utilities analyzed here made use of some form of conservation rate.[4] The top map in Figure 2 shows the distribution of utilities with and without conservation rates across the United States. Not surprisingly, more utilities appear to use conservation rates in the water-scarce areas of the country, especially the West, Southwest, and Florida. In the Midwest and Northeast, there are fewer utilities that have conservation rate structures.

But what about the progressivity of those rate structures? While most utilities still use uniform rates, there is a good deal of variation in the progressivity of the adopted rate structures. The average rate progressivity among cities with populations of 20,000 or more that run their own utility is 0.096. This means that, for every 1,000 gal in increased

TABLE 2 Descriptive statistics for variables included in analysis

Variable	Percentage	Mean	*SD*	Min	Max
Binary variables					
Conservation rate structure	53.404				
Groundwater supply	24.531				
Purchased water supply	31.455				
Continuous variables					
Rate progressivity		0.096	0.178	−0.683	1.549
City policy conservatism		−0.053	0.272	−0.999	0.647
Palmer Drought Severity Index		−0.141	1.500	−3.630	2.797
Logged population		11.161	0.813	10.014	15.951
Percent change in population, 2000–2016		17.167	27.275	−28.155	332.005
Population density (residents/mile^2)		3,514.543	2,841.315	47.094	28,172.54
Percent black		13.300	16.482	0.124	90.666
Percent Hispanic		18.464	19.066	0.696	97.98
Percent with bachelor's degree		30.825	14.446	5.6	81.4
Percent below poverty		17.052	8.600	3	50.2
Median household income ($1,000s)		54.382	19.763	23.09	159.167

Note. n = 852. Max: maximum; Min: minimum; *SD*: standard deviation.

consumption, the price per 1,000 gal will increase about 10 cents. The geographic distribution of rate progressivity in the United States can be seen in the bottom map of Figure 2.

6 | THE CORRELATES OF RATE PROGRESSIVITY IN U.S. MUNICIPALITIES

It is possible to explore utility conservation policy in a more detailed way. A multivariate statistical analysis can help explore the correlates of water rate progressivity as well as demonstrate potential differences in the types of inferences that can be drawn when using the new continuous measure instead of the dichotomous measure of conservation rates. Exploring the correlates of both rate progressivity and conservation rate adoption will help to show whether the new measure can provide different explanations for utility policies than the dichotomous approach.

6.1 | Data

Several potential variables can influence the adoption of progressive water rates. Descriptive statistics for all variables can be found in Table 2.

First, citizen ideology may play a role in the level of progressivity. Recent research has shown that local governments, which own and operate all the utilities examined here, are quite responsive to the preferences of the citizens they serve (Tausanovitch & Warshaw, 2014; Einstein & Kogan, 2016; Switzer, 2017). Given the literature that has found liberal citizens are more supportive of conservation (Bishop, 2013; Hannibal, Liu, & Vedlitz, 2016; Switzer & Vedlitz, 2017), I suggest that utilities serving more liberal citizens will adopt more progressive rates than those serving more conservative citizens. I use Tausanovitch and Warshaw's (2014) data set of city policy conservatism to measure ideology.

Resource constraints likely also play a large role in the adoption of conservation rates. Research has found that climate is an important determinant of the adoption of conservation rates (Mullin, 2008; Teodoro, 2010). To measure water scarcity, I use the average monthly Palmer Drought Severity Index (PDSI) for the National Oceanic and Atmospheric Administration (NOAA) climate divisions containing each utility for the 10-year period from 2007 to 2016. The PDSI, ranging from −4 for extremely dry regions to 4 for extremely wet regions, is the most commonly used measure of regional moisture and assigns values to the level of water supply/demand in a region (Palmer, 1965). Water source may also determine the necessity of conservation. Groundwater may be less affected by scarcity, and utilities that purchase their water through wholesalers may have less incentive to adopt conservation rates (Teodoro, 2010). I drew source data from the U.S. Environmental Protection Agency Safe Drinking Water Information System and included dummy variables for whether a utility used groundwater and purchased water.

Population characteristics may influence rate conservation policy as well. Larger utilities may be more likely to adopt progressive rates, as the implementation of complex rate structures may require more technical sophistication that small utilities lack (Teodoro, 2010). Smaller utilities may lack the administrative capacity to implement more complex rate structures. Population density may also affect the demand for conservation rates. More densely populated cities may lower peak water demand as a result of less lawn space, making conservation less necessary. Finally, increasing population may put a strain on a utility's resources. To control for these possibilities, I used data from the 2016 American Community Survey (ACS) 5-year estimates and the 2000 decennial census, including measures of the natural log of population and the residents per square mile in 2016, as well as the percent population change from the 2000 decennial census to the 2016 ACS.

Demographics may play a significant role in rate progressivity. The public opinion literature has long found that minorities have higher levels of environmental concern, and it is therefore possible that utilities serving more black and Hispanic residents will be more likely to adopt progressive rates (Kahan, Braman, Gastil, Slovic, & Mertz, 2007). I included variables for the percentage of the population in the municipality that was black and Hispanic in 2016. More educated individuals also tend to be more supportive of environmental protection and conservation (Van Liere & Dunlap, 1980; Switzer & Vedlitz, 2017). I included a measure of the percentage of the population with a bachelor's degree or higher, as cities with more educated populations may adopt more progressive rates.

Rate structures also have significant redistributive implications (Berry, 1979; Mullin, 2008; Teodoro, 2018). The measure here primarily captures conservation and not redistribution, as it does not contain fixed prices, which do not affect the marginal price of consumption but are important from a distributive perspective. Still, more progressive rates may be more common where there are large numbers of poorer individuals in order to facilitate affordability. For this reason, I included a measure of the percentage of the population below the poverty line in 2016. Finally, water usage is correlated with income (Mullin, 2008). Wealthier individuals may be opposed to more progressive rates as they would be the ones paying, so I include a measure of median household income.

6.2 | Models

To evaluate the differences in correlates between the dichotomous measure of conservation rates and my continuous measure, I use seemingly unrelated regression (SUR) with an ordinary least square (OLS) estimator. This allows for a formal test of cross-model equivalence of the effect of covariates, illustrating how they differ between the dichotomous and continuous new measures. In the case of the dichotomous rate structure model, this ends up estimating a linear probability model predicting the adoption of seasonal or increasing block rates.[5] I coded the dependent variable 1 if the rate structure is conservation oriented and 0 if it is not. The second regression contained the new measure of rate progressivity as the dependent variable.

7 | RESULTS

Table 3 shows the results of the SUR models for conservation rates and rate progressivity. The left two columns show the results of the linear probability model predicting conservation rate adoption, while the middle two columns show the results of the OLS model predicting rate progressivity. The right two columns show the results of the SUR tests of cross-model equivalence, with the null representing equivalent effects across models. This is a significant finding that implies statistically different effects for the variable across models.

While many of the covariates do not have equivalent effects across models, in every case but one, the direction of the relationship is the same in both models for every covariate. In both models, the PDSI average has a strong and negative relationship with conservation. As average moisture over the 10-year period increases, utilities become less likely to adopt conservation rates, and their rate structures become less progressive, although the effect is statistically larger in

TABLE 3 Predicting conservation rate adoption and rate progressivity

	Conservation rate		Rate progressivity		Model equivalence	
Covariate	Coefficient	*p*-Value	Coefficient	*p*-Value	χ^2	*p*-Value
City policy conservatism	0.101 (0.082)	0.219	−0.092 (0.036)	0.010	6.61	0.010
Palmer Drought Severity Index	−0.091 (0.012)	<0.001	−0.026 (0.005)	<0.001	34.49	<0.001
Groundwater supply	0.124 (0.040)	0.002	0.005 (0.014)	0.713	10.03	0.002
Purchased water supply	0.022 (0.042)	0.595	0.040 (0.016)	0.012	0.21	0.650
Logged population	0.059 (0.022)	0.006	0.016 (0.009)	0.078	5.11	0.024
Percent change in population	0.002 (0.001)	0.001	0.001 (0.000)	0.010	6.32	0.012
Population density	−0.000 (0.000)	0.375	−0.000 (0.000)	0.100	0.02	0.901
Percent black	0.003 (0.001)	0.011	0.000 (0.000)	0.311	5.86	0.012
Percent Hispanic	0.004 (0.001)	0.003	0.000 (0.001)	0.433	7.05	0.008
Percent with bachelor's degree	0.006 (0.002)	0.003	0.002 (0.001)	0.006	4.09	0.043
Percent below poverty	−0.010 (0.004)	0.008	−0.004 (0.002)	0.027	3.28	0.070
Median household income ($1,000s)	−0.001 (0.002)	0.479	−0.002 (0.001)	0.012	0.09	0.764
Constant	−0.217 (0.288)	0.451	−0.001 (0.113)	0.995		
Observations	852		852			

Note. Standard errors in parentheses.

the conservation rate dichotomous model. Still, these results suggest that utilities respond to the scarcity of their region.

Contrary to expectations, the use of groundwater and purchased water is associated with more conservation-oriented rates in both models, although the effect of groundwater is only significant in the conservation rate model, and the effect of purchased water is only significant in the progressivity model. The null of effect equivalence is rejected in the case of groundwater but not rejected in the case of purchased water. This is an interesting finding and perhaps worth further exploration because, in expectation, groundwater and purchased water should be less affected by regional scarcity.

The results for the population variables mostly conform to expectations, with higher logged population and increasing percentage change in population both positively associated with conservation rate adoption and more progressive rates, although the effect of logged population is only significant at the 0.10 level in the rate progressivity measure, and the null of equivalence is rejected in both cases. Utilities appear to respond to the challenges of their populations. Large and growing populations place supply-side constraints on resources, and these results suggest that utilities are responding. Population density is not statistically significant in either of the models, and the effect is statistically equivalent.

While the coefficients for percent black and percent Hispanic population are positive in both models, they are only statistically significant at the 0.05 level in the model predicting conservation rate adoption, and they are not statistically equivalent across models. Again, this finding may be worth exploring in more detail as it appears that the effect of race and ethnicity is not as strong once the continuous measure is considered. Cities with more educated populations, as expected, had more conservation-oriented rates in both models, while higher poverty rates were surprisingly associated with less conservation rate adoption and lower progressive rates. The models were not statistically equivalent at the 0.05 level in the case of education and at the 0.10 level in the case of poverty. Finally, while both models showed a negative effect of income, it was only statistically significant in the model predicting progressivity, but the null of model equivalence was unable to be rejected. In general, socioeconomic status matters but not in a consistent way.

While there is some statistical difference in the effect of many of the variables across the two models, the direction of the effects demonstrates little difference in the inferences to be drawn, with the direction of most of the variables remaining consistent across models. The major divergence in the results, however, concerns the effect of citizen ideology. When considering just the adoption of conservation rates as a dichotomous variable, we might conclude that ideology shows no significant association with utility rate conservation policy. There is no statistically significant effect of citizen ideology on the adoption of conservation water rates. Indeed, contrary to expectations, increasing citizen conservatism actually has a positive, albeit statistically nonsignificant, effect on conservation rate adoption.

This is in stark contrast with the findings of the model predicting rate progressivity, where ideology has a strong and significant relationship with conservation policy, and the effect is statistically different across models. Utilities serving conservative populations have significantly fewer progressive rate structures than those that serve liberal populations. This is not only a statistically significant relationship at the 0.01 level but at a substantively large one as well. A two *SD* decrease in citizen conservatism (or increase in liberalism) leads to a predicted increase of 0.050 in the slope measure. This is in contrast to the probability of conservation rate adoption, where the same decrease in policy conservatism leads to an insignificant decrease in the predicted probability of conservation rate adoption of 0.055. While many of the inferences about utility conservation would be similar whether a dichotomous or continuous measure of rate conservation is used, the findings for ideology show that something may be missed if the rich variation within water rate types is not recognized.

What makes this finding especially interesting is what it may suggest about the nature of rate adoption. While adopting seasonal or increasing block rates may signal a nominal commitment to conservation, it does not necessarily mean a utility is increasing the marginal price of water to a point where it will make a significant difference to conservation. That ideology has an effect on rate progressivity but not rate structure type suggests that the political costs of a nominal commitment to conservation through rate structure type may be low but that actually creating a rate structure that will encourage conservation through price increases on higher-volume users may require a supportive public.

8 | DISCUSSION

The primary contribution of this article is in developing a new way of measuring water utility rate progressivity across utility types. This new measure allows for a deeper understanding of utility commitment to conservation by accounting for the rich variation in water rates that can be adopted. This provides a substantial improvement on a dichotomous understanding of water rate structures, which would consider even drastically different rate structures to be identical because of a nominal commitment to conservation. While no measure is perfect, and the linearity assumption of the measure developed here does provide some limits, moving beyond a dichotomous approach to rate structures is an important step in understanding the variety of approaches utilities take to the issue of conservation. Future research should consider other ways of measuring rate progressivity, including ordinal approaches.

This new measure can prove useful in several ways. First, it has practical uses. It allows for a simple understanding of water rate progressivity that nonetheless captures that nuance of the rate structure. It can allow for comparisons between utilities and broad understandings of groups of utilities that could be useful to water professionals and policymakers. While individual utilities can look at their own rates in greater depth than this measure allows, the measure should be especially useful to state-level organizations and agencies. Many state governments perform studies of the rate structures used by the utilities within their state. This measure would allow for a broad comparison of the progressivity of those utilities. It would provide valuable information to regulators and policymakers who want to encourage higher levels of water conservation. In addition, the issue of water affordability is an issue of growing interest in the water industry (Teodoro, 2018, 2019). Water affordability will generally mean that marginal prices for low-volume use should be low, which is also true of progressive rate structures, so there is a potentially important relationship between affordability and progressivity that should be explored. As Teodoro (2018, p. 22) suggests, "Better measurement can facilitate better decisions." Careful measurement of progressivity provides another tool for decision makers when addressing issues of affordability and conservation.

The measure also has tremendous use from a research perspective. As it represents a utility's commitment to water conservation, it can be used as a continuous measure of utility water conservation policy that can be used across various disciplines. An immediate question that could be explored is the differences in progressivity among the types of organizations responsible for utility services. While the analysis here focused on municipal utilities, water services are provided by municipalities, counties, special districts, investor-owned utilities, and not-for-profit cooperatives in some cases. These different types of utilities face radically different political, economic, and administrative incentives that may lead to different levels of rate progressivity. Exploring these differences using this measure could inform a number of policy debates, especially in the case of investor-owned utilities, which have become an area of controversy in the water industry. It would also be interesting to explore whether progressivity affects conservation in a meaningful way. The analysis here looks at progressivity as a dependent variable, but it is easy to imagine it as an independent variable as well. Understanding water conservation policy necessarily means measuring it, and this new measure of rate progressivity provides an important avenue for exploration.

ENDNOTES

[1] When compared with the other 850 utilities in the data set assembled here, Annapolis' highest marginal rate of $10.12 is in the 93rd percentile of highest marginal rates for the first 30,000 gal. Fullerton's highest price of $3.71 is in the 39th percentile.

[2] For utilities that use seasonal rates, I took the average price per 1,000 gal across seasons for each 1,000-gal block. Alternatively, it would be reasonable to take just the prices from the highest demand season.

[3] The choice of 20,000 people is due to data availability. The ideology data from Tausanovitch and Warshaw (2014) used in the analysis are only available for cities with 20,000 people or more, so I used that as my frame in order to have ideology data for all cities in the data set. Data were collected in the summer of 2017. A total of 53 municipalities with more than 20,000 people did not list their rate structures online and so were not included in the analysis; 12 utilities use water budgets, which are a type of rate structure that determines the price per unit based on prior levels of usage or property size. They do not assign prices to blocks and thus are unable to be included in the analysis here. The data set contains rates only for cities in the 48 contiguous states. Hawaii and Alaska are not included in the NOAA climate divisions, limiting the usage of the PDSI data for these states.

[4] Those that included elements of both increasing and decreasing block rates were considered conservation oriented for the purpose of this analysis as most only had decreasing blocks at extremely high levels of consumption.

[5] I use the linear probability model instead of a logistic regression because it allows me to use SUR to test the equivalence of the effects across models. The results using a logistic model can be seen in Appendix S1 (Supporting Information) and do not differ greatly from those displayed here.

REFERENCES

Aubuchon, C., & Roberson, J. A. (2012). Price perception and nonprice controls under conservation rate structures. *Journal AWWA*, *104*(8), 446–456. https://doi.org/10.5942/jawwa.2012.104.0101

Berry, W. D. (1979). Utility regulation in the states: The policy effects of professionalism and salience to the consumer. *American Journal of Political Science*, *23*(2), 263–277.

Bishop, B. H. (2013). Drought and environmental opinion: A study of attitudes toward water policy. *Public Opinion Quarterly*, *77*(3), 798–810.

Campbell, H. E., Johnson, R. M., & Larson, E. H. (2004). Prices, devices, people, or rules: The relative effectiveness of policy instruments in water conservation. *Review of Policy Research*, *21*(5), 637–662.

Chestnutt, T. W., Beecher, J. A., Mann, P. C., Clark, D. M., Hanemann, W. M., Raftelis, G. A., … Krop, R. (1997). *Designing, evaluation, and implementing conservation rate structures*. Sacramento, CA: California Urban Water Conservation Council.

DeOreo, W. B., Mayer, P. W., Dziegielewski, B., & Kiefer, J. (2016). *Residential end uses of water version 2*. Denver, CO: Water Research Foundation.

Einstein, K. L., & Kogan, V. (2016). Pushing the city limits: Policy responsiveness in municipal government. *Urban Affairs Review*, *52*(1), 3–32.

Griffin, D., & Anchukaitis, K. J. (2014). How unusual is the 2012–2014 California drought? *Geophysical Research Letters*, *41*(24), 9017–9023.

Hannibal, B., Liu, X., & Vedlitz, A. (2016). Personal characteristics, local environmental conditions, and individual concern: A multilevel analysis. *Environmental Sociology*, *2*(3), 286–297.

Kahan, D. M., Braman, D., Gastil, J., Slovic, P., & Mertz, C. K. (2007). Culture and identity-protective cognition: Explaining the white-male effect in risk perception. *Journal of Empirical Legal Studies*, *4*(3), 465–505.

Kenny, J. F., Barber, N. L., Hutson, S. S., Linsey, K. S., Lovelace, J. K., & Maupin, M. A. (2009). *Estimated use of water in the United States in 2005*. Reston, VA: U.S. Geological Survey.

Levin, R. B., Epstein, P. R., Ford, T. E., Harrington, W., Olson, E., & Reichard, E. G. (2002). US drinking water challenges in the twenty-first century. *Environmental Health Perspectives*, *110*(Suppl. 1), 43–52.

Liere, K. D. V., & Dunlap, R. E. (1980). The social bases of environmental concern: A review of hypotheses, explanations, and empirical evidence. *Public Opinion Quarterly*, *44*(2), 181–197.

Lippiatt, B. C., & Weber, S. F. (1982). Water rates and residential water conservation. *Journal AWWA*, *74*(6), 278–281. https://doi.org/10.1002/j.1551-8833.1982.tb04919.x

Mullin, M. (2008). The conditional effect of specialized governance on public policy. *American Journal of Political Science*, *52*(1), 125–141.
Palmer, W. C. (1965). *Meteorological drought*. Washington, DC: U.S. Department of Commerce, Weather Bureau.
Switzer, D. (2017). Citizen partisanship, local government, and environmental policy implementation. *Urban Affairs Review*. https://doi.org/10.1177/1078087417722863
Switzer, D., & Vedlitz, A. (2017). Green colored lenses: Worldviews and motivated reasoning in the case of local water scarcity. *Environment and Behavior*, *49*(7), 719–744.
Tausanovitch, C., & Warshaw, C. (2014). Representation in municipal government. *American Political Science Review*, *108*(3), 605–641.
Teodoro, M. P. (2010). The institutional politics of water conservation. *Journal AWWA*, *102*(2), 98–111. https://doi.org/10.1002/j.1551-8833.2010.tb10055.x
Teodoro, M. P. (2018). Measuring household affordability for water and sewer utilities. *Journal AWWA*, *110*(1), 13–24. https://doi.org/10.5942/jawwa.2018.110.0002
Teodoro, M. P. (2019). Water and sewer affordability in the United States. *AWWA Water Science*, *1*(2), 1–10. https://doi.org/10.1002/aws2.1129
Whitcomb, J. B. (2005). *Florida water rates evaluation of single-family homes*. West Palm Beach, FL: South Florida Water Management District.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Switzer D. Introducing a new measure of residential water rate progressivity. *AWWA Wat Sci*. 2019;e1132. https://doi.org/10.1002/aws2.1132