Is the Policy Enough? Adoption and Impacts of Tiered Water Pricing in Utah, 1980 - 2022

Savanna Craig, Kalli Hull, Steven W. Wilcox*

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Abstract

Many municipalities and water districts in the arid Western U.S. adopt tiered water pricing to encourage conservation. Evidence on the effectiveness of tiered pricing is limited. Using 43 years of data from Utah, we study the diffusion of tiered pricing and its extensive-margin effect on water use. We construct a municipal-level panel that includes water use, pricing structure, population, and weather, and we estimate impacts on water use using staggered difference-in-differences. We find that tiered pricing adoption has a null effect on water use. This suggests that simply having a tiered pricing policy is insufficient for accomplishing meaningful water conservation.

Keywords: tiered pricing, municipal water, water conservation, Utah

JEL classification: Q25, Q28, Q58, L95

*Correspondence to be sent to: Savanna Craig, WestWater Research, craig@westwaterresearch.com. Hull: kallihull15@gmail.com. Wilcox: Department of Agricultural and Resource Economics, Utah State University (USU), Logan, UT 84322, USA, steven.wilcox@usu.edu. We gratefully acknowledge financial support from the Department of Agricultural and Resource Economics at Utah State University. We are grateful for helpful comments received from Ryan Bosworth, Man-Kuen Kim, Arthur Caplan, Man Li, municipal water managers in Utah, staff at UDWRi, and seminar participants at Utah State University, Colorado State University and the AERE summer conference. Wilcox is a faculty affiliate of the USU Ecology Center and the Berryman Institute. All errors are our own.

1 Introduction

Water managers worldwide face daunting challenges in conserving and overseeing water use, especially in arid regions prone to drought. In these settings, policymakers must balance equitable access and affordability with pressures to curb excessive use through price and non-price policy tools (Olmstead and Stavins 2009). These challenges raise important questions about when and how conservation policies achieve their intended goals. Yet in many contexts where evidence is most needed, municipal- or district-level data are often limited and policies are implemented without rigorous evaluation frameworks, leaving information gaps that impede effective resource management.

In this paper, we address these challenges in the empirical setting of Utah and provide new evidence on the adoption and impacts of tiered water pricing (i.e., increasing block pricing). Utah is among the driest states in the United States, it is experiencing rapid urban and population growth, and is currently experiencing prolonged historic drought. The state also faces many critical water challenges related to the Colorado River, the Great Salt Lake, agriculture, and climate change (Khatri and Strong 2020; Kem C. Gardner Policy Institute 2021; Frankson et al. 2022; Flavelle and Tarnowski 2022; Sowby 2024). Using 43 years of municipal-level data on water use, pricing structures, population, and weather, we implement a novel test of the extensive-margin effect of tiered water pricing — specifically, whether merely having a tiered pricing policy affects water use.

We merge publicly available municipal water use, population, and weather data with new survey data from municipal water managers tracking the first year of tiered pricing adoption. To estimate the extensive-margin effect, we use a two-stage staggered difference-in-differences (DiD) estimator (Gardner et al. 2025), which is robust to heterogeneity in treatment timing and effects. We find that tiered pricing adoption does not have a statistically significant impact on culinary water use. While estimates of the overall effect are generally negative, we cannot reject the null hypothesis of no effect.

Our study is timely given current water conservation challenges in Utah and the arid Western United States (U.S.) as well as recent legislation in Utah. Senate Bill 28 (SB28), titled *Water System Conservation Pricing*, passed into law in 2016 and requires Utah municipalities to adopt tiered water pricing (Utah State Legislature 2016). Notably, SB28 does not impose penalties for non-compliance, emphasizing voluntary action and reflecting Utah's historically conservative regulatory culture. Because of the statewide nature of the policy and available data, our tests do not directly assess the efficacy of this legislation, nor do they permit intensive-margin tests (e.g., variation in tier numbers or price levels). Nevertheless, our analysis directly addresses a key, implied assumption of SB28: that simply adopting tiered pricing may induce conservation. Our results suggest this assumption is unlikely to hold in practice, highlighting that tiered pricing alone may be insufficient to achieve meaningful water savings. These findings speak more broadly to questions about the aggressiveness of pricing structures needed to achieve conservation goals, particularly with largely price-inelastic demand, and the role of legislation in maximizing the effectiveness of pricing tools.

Our work contributes to the water economics literature in several ways. First, we provide the first known study of the adoption and impacts of tiered pricing in Utah. While a few studies have applied econometric methods to analyze water demand in Utah's major metropolitan area and provide policy-relevant insights (e.g., Coleman 2009; Edwards and Sutherland 2019), Utah and the arid Mountain West remain under-studied by economists. We therefore provide new evidence from a region and policy environment that has received limited attention despite broad interest in Utah's water resource management.

A second contribution centers on our question and data. While the water economics literature is extensive, studies of urban or residential water and related utility pricing topics have historically emphasized policy design and price responsiveness (Taylor 1975; Nordin 1976; Billings and Agthe 1980; Agthe and Billings 1987), estimating water demand (Dalhuisen et al. 2003; Olmstead, Hanemann, and Stavins 2007; Grafton et al. 2011; Clarke, Colby, and

Thompson 2017; Sebri 2014), consumer responses to price signals (Nataraj and Hanemann 2011; Baerenklau, Schwabe, and Dinar 2014; Ito 2014; Wichman 2014), and evaluating the merits of price and non-price policy tools (Wichman, Taylor, and Von Haefen 2016; Baker 2021; Brelsford and Abbott 2021; El-Khattabi et al. 2021). Much of this work examines micro-level behavior or specific urban settings. Few studies examine policy diffusion at regional or state levels or evaluate impacts over longer time horizons. By focusing on municipal variation and the extensive margin of policy, we bring a unique perspective to the literature.

Finally, our contributions are relevant to the literature on price salience and the behavioral economics literature on water. Prior work has established the importance of cost information being clear and salient in eliciting behavioral responses, and the complexity of tiered rates may help explain why evidence suggests that average prices matter more than marginal prices (Chetty, Looney, and Kroft 2009; Ito 2014; Wichman 2014). A number of recent studies have also examined how informational interventions, such as social comparisons, social norms, and other behavioral nudges, affect water use (Ferraro and Price 2013; Brent, Cook, and Olsen 2015; Brent and Ward 2019; Jessoe et al. 2021; Vivek, Malghan, and Mukherjee 2021; Burkhardt et al. 2022). To be clear, our work is non-experimental and does not directly test behavioral hypotheses. Nevertheless, moving from a flat-rate or uniform pricing structure to an increasing tiered rate conveys new information to consumers about how water costs rise with higher use, which may itself induce changes in consumption – even if most households do not experience a change in their bills. In this light, although we do not observe how information about the policy was communicated across municipalities, our extensive-margin tests provide evidence on whether the presence of a tiered pricing policy – and the cost information it implicitly conveys – affects water use.

The remainder of this paper proceeds as follows. Section 2 describes the empirical setting of Utah and Section 3 summarizes our data. In Section 4 we detail our econometric strategy, Section 5 presents our results, and Section 6 concludes.

2 Empirical Setting

Utah is considered the third driest state in the United States, and it is largely split hydrologically between the Great Basin and the Colorado Plateau, an important sub-region of the Colorado River basin (Sowby 2024). Although Utah has advantages when it comes to water, which largely comes from winter mountain snowpack, it also is experiencing a variety of high-profile water challenges, including concerns around excessive diversions of inflows to the Great Salt Lake and over-allocation of the Colorado River, that are likely being exacerbated by historic drought and climate change (Flavelle and Tarnowski 2022; Colorado River Water Users Association 2024; Wang et al. 2025; Great Salt Lake Strike Team 2026; Frankson et al. 2022). Utah is also among the fastest growing populations in the United States, with rising demands from expanding urban populations and competing demands from agriculture and industry that compound the aforementioned environmental challenges (Kem C. Gardner Policy Institute 2021; Great Salt Lake Strike Team 2026).

From a policy perspective, particularly since the latter half of the 20th century, Utah has been comparatively conservative and not particularly aggressive from a legislative perspective on a variety of topics, including water (Caughey and Warshaw 2016). Water in Utah, like much of the arid western US, is governed by the prior appropriation doctrine, commonly referred to as "first in time, first in right", and a complex network of municipal providers, local irrigation companies, and federal and state water districts manage the state's water. Variation in price and non-price tool adoption has historically largely been left to local jurisdictions. According to a 2013 survey of municipalities, 2% had a decreasing block structure, 7% had a flat rate, 26% had a uniform rate, 25% had an increasing tiered rate, and 21% had an unknown rate structure (Edwards and Sutherland 2019).

Given the variety of current and expected water challenges that Utah is facing, water use in any sector is under scrutiny. A 2015 legislative audit titled, *A Performance Audit of Projections of Utah's Water Needs*, offers a useful window into the state's perspective on water challenges (Office of the Legislative Auditor General 2015). This audit makes several suggestions regarding water in Utah, such as methods for improved reporting accuracy, recommendations for establishing conservation goals and policy tools to achieve conservation, and updating and maintaining databases that record available water levels and historical water transfers. One of the recommendations made for achieving conservation is to require an increasing block rate structure for culinary water customers in Utah. In 2016, the Utah Legislature was able to create and pass a bill, the aforementioned SB28 (see Section 1), that follows through on this recommendation (the full bill comprising SB28 is provided in Appendix A). The legislation is very brief, and requires retail water providers in Utah to adopt an increasing block rate structure for their culinary water customers. The bill does not specify the number of blocks a provider should use, what price to charge, or how big the blocks should be – nor is there a penalty for non-compliance. Our study ostensibly tests this comparatively light-handed approach to regulating how local water supplies should manage and price water in their jurisdictions.

3 Data and summary statistics

3.1 Data

3.1.1 Units of observation and municipal culinary water use data

Our primary units of observation are the universe of municipalities in Utah, which are the primary form of local government in the state. To merge water use data and weather data we use a shapefile of municipality spatial boundaries from the Utah Geospatial Reference Center (Utah Geospatial Resource Center 2025). During our period of study, there are 250 unique municipalities in the data.[1] Of these 250 units, we were able to match available water use data for 242 municipalities.

Our primary source of water use data comes from Utah Division of Water Rights Water Records (UDWRi-WR) (Utah Division of Water Rights 2024). From the UDWRi-WR website one can access annual water use data for municipalities in PDF format. We download all municipality PDFs and use the R package *pdftools* to scrape each PDF to construct a panel of municipality specific data (Ooms 2025). These data reflect self-reported measures of residential, commercial, industrial, and institutional water use and population going back, in some cases, to the early 1980s.

Concerns have been raised over measurement error in UDWRi-WR data. This is an issue that was raised in the aforementioned 2015 audit and, starting in 2015, there have reportedly been increased efforts to improve quality (Office of the Legislative Auditor General 2015). The raw data indeed do contain extreme outliers and significant missingness, particularly for smaller municipalities and years prior to 1990. To address missingness across the entire sample, we apply a loop to identify cases of non-consecutive zeros or NAs in water use and population. Respective instances were imputed using the mean of the pre- and post-missing values (i.e., cases where accurate data was reported in the year before and the year after a 0 or NA). In the subset used for DiD estimation, these imputations were carefully assessed for quality on a per municipality basis and adjusted as needed. Extreme outliers are either set to missing or imputed using the aforementioned technique. The resulting data comprise an unbalanced panel of municipal-level consumption and population data spanning 1980-2022.

Among the variables present in these data, we focus on the available residential culinary water consumption data, reported in acre-feet per year, and respective population data.

[1] The available shapefile contains 254 unique boundaries, however, four of these units reflect municipalities that are located on the boundary between counties and recorded in two separate polygons. To address this we removed duplicate polygons that were very small and not likely to contribute meaningful spatial variation in weather, thus leaving 250 unique municipalities. These respective 4 municipalities include: Bluffdale, on the border of Salt Lake County and Utah County; Draper, on the border of Salt Lake County and Utah County; Park City, on the border of Wasatch County and Summit County; and Santaquin, on the border of Utah County and Juab County.

Residential culinary water consumption data captures the majority of municipal water use which can be directly tied to variation in pricing policies. This combination of data also permits measurement in terms of use per capita and use of population for weighting purposes. An important facet of culinary water use data in Utah is that some water users have access to secondary water for outdoor irrigation (e.g., a non-potable supplementary source from a different provider) and others do not. During our study period, these characteristics are likely fixed. In our survey of municipal water managers, we gather some data on this question.

3.1.2 Municipal culinary water price data

We take two complimentary approaches to gather culinary water price data. First, in 2022 we gathered as much data as possible on contemporaneous rates by searching municipality websites. Most municipality websites only had data for for the current year's prices. We use these data to construct a cross-section of contemporaneous variation in base rates, tiers, and marginal prices within tiers for descriptive purposes.

Second, to collect data on past water pricing history for municipalities, we designed and implemented a web-based survey of municipal water managers titled the, *Utah Culinary Water Pricing Survey*. The respective survey instrument is provided in Appendix B along with a table of the municipalities that responded to the survey organized by county and self-reported tiered pricing adoption status (see Table B.1). The survey was sent to 239 out of 250 contacts found for municipalities in January of 2024. Follow-up emails were sent to the municipalities that did not respond to the first send out in February and March of 2024. Out of the municipalities contacted, we received 98 total responses. Of the 98 responses, 94 indicated whether they have adopted tiered pricing for their culinary water customers, and 79 of the 94 indicated the year the policy was adopted. Among the 29 counties in Utah, at least one municipality from 26 counties responded. Counties with no responses include Juab, Wasatch, and Daggett. Therefore roughly 40% of the municipalities in our data responded to the survey, the sample is widely distributed throughout the state and captures the major population centers in the state. In addition, 25 municipalities also reported the water price that was in place prior tiered pricing adoption.

We leverage these data in several ways. First, we convert all available price data to values in real terms using the implicit price deflator from the U.S. Federal Reserve Bank of St. Louis using 2017 as the base year (U.S. Federal Reserve Bank of St. Louis 2024). Second, using data on the year of tiered pricing adoption we can code years when tiered pricing was in effect. Third, using contemporaneous pricing data and population data, we can recover the effective price faced by consumers and compare these rates to pre-tiered pricing rates reported by municipal water managers.

3.1.3 Weather Data

Although our culinary water use data vary annually, variation in monthly weather may have some relevance to year-to-year use. For example, hot summer months may be associated with higher annual use in settings without access to secondary water. To account for this, we gather monthly data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) to capture weather variation at the municipal level (Daly et al. 2008). We use the aforementioned municipality spatial boundaries to gather covariates using available 4km resolution raster data. The majority of municipalities are larger than 4km and the smallest municipality boundaries intersect with at least one pixel. We collect monthly maximum and minimum temperatures (°C) over 1980-2022 to calculate monthly average temperatures as well as total and average precipitation (mm).

3.2 Summary Statistics

Figure 1 characterizes important variation that arises from responses to our survey of municipal water managers, the *Utah Culinary Water Pricing Survey*. The top panel of Figure 1 shows the spatial distribution of responses to the survey and the bottom panel shows the count of municipalities that adopted tiered water pricing for culinary water by year among the 79 municipalities that indicated the first year of adoption. As demonstrated by Figure 1, our survey data captures very good representation across Utah, including large municipalities in northern and southern Utah (e.g., Salt Lake City and St. George), and broad representation of smaller urban and rural municipalities within 26 of Utah's 29 counties. The bottom panel of Figure 1 also shows that adoption of tiered water pricing occurred as early as 1980 and has steadily increased since 2000.

Figures 2 and 3 respectively summarize variation in municipal water use and population, and variation in panel imbalance, within the available UDWRi-WR data over 1980-2022. Figure 2 juxtaposes average municipal population over this period with the distribution of municipal culinary water use captured by the 75th, 50th, and 25th percentiles in acre-feet. The top panel of Figure 2 shows the distribution among the municipalities that responded to the *Utah Culinary Water Pricing Survey* and the bottom panel shows the distribution among all 242 unique municipalities in the UDWRi-WR data. Similarly, the top panel of Figure 3 shows a count of the number of municipalities that report annual water consumption/use data among the municipalities that responded to the *Utah Culinary Water Pricing Survey*, and the bottom panel shows the same count among all municipalities in UDWRi-WR data.

A number of important facts emerge from Figures 2 and 3. First, the distributions among the set of municipalities that responded to the *Utah Culinary Water Pricing Survey*, and the full set of 242 unique municipalities in the UDWRi-WR data, are very similar. This suggests that the subset of data suitable for our tests of the extensive margin effect of having tiered water pricing on water use is not systematically different than the variation present in the full universe of UDWRi-WR data. Second, there is significant variation across municipalities and significant growth in average population over time. The municipal water use distribution is also heavily skewed above the median and population has exhibited steady and increasing growth since the mid 1990s. Third, the median level of consumption has stayed quite stable over time despite steady population growth, but it also exhibits a marginal decline after the early 2010s. Fourth, somewhat large swings in the distribution prior to 1990 are apparent, which can in part be attributed to the increasing number of municipalities that report water use data starting in the mid 1980s and into the early 1990s as made clear in Figure 3. As Figure 3 demonstrates, it was not until 2015 that nearly all municipalities were reporting among the 242 unique municipalities found in the UDWRi-WR data. Clearly, the extent of missingness is a shortcoming reflected in the aforementioned 2015 audit (Office of the Legislative Auditor General 2015). Panel imbalance is not generally a problem for staggered DiD estimator developed by Gardner et al. (2025). We elaborate on robustness checks in Sections 4 and 5.2.

Although the available data offer a very limited view of price variation at the intensive margin, our efforts to gather data in contemporaneous tiered pricing structures and pre-tiered pricing variation provide important insights. Figure 4 showcases examples of some of this variation. The top panel of Figure 4 shows variation from some of the extremes in tiered structures in 2022 in real terms juxtaposed against estimates of the implied average rates based on estimates of average monthly culinary water use in 2022.[2] The bottom panel of Figure 4 shows boxplots of the distribution of monthly culinary water rates, pre- and post-tiered pricing, along with lines depicting respective regional average rates. In the top panel of Figure 4, it is apparent that some municipalities have adopted seemingly aggressive steeply increasing structures with few or many tiers (e.g., Park City versus Fairview), while others seem less aggressive with few tiers that do not increase steeply with quantity (e.g., Lewiston and Clinton). Regardless, the estimated average consumption rate implies that the average consumer experiences the lowest tier and monthly rate possible. Although this is a rough approximation based on the best-known data available, the implication is that these rate structures may not be forcing residents to face increasing costs of consumption.

[2]Most municipal water in Utah is billed on the monthly basis, so the rate structures in the top of Figure 4 should be viewed through a monthly consumption and pricing perspective. Since the water use data in the available UDWRi-WR data are annual, we approximate monthly consumption per capita by dividing total annual consumption by 12 and then dividing that number by the reported 2022 municipal population.

The bottom panel of Figure 4 offers additional suggestive evidence that adoption of tiered rates may not necessarily be resulting in higher costs on culinary water consumption for many residents in Utah based on estimated monthly price variation in real terms. The bottom left boxplot shows the distribution of self-reported average real monthly prices without tiered pricing along with the averages for southern versus northern Utah based on responses to the *Utah Culinary Water Pricing Survey*. The bottom right boxplot shows the distribution of estimated average real monthly prices based on average consumption in gallons per capita, along with the implied average prices for responses in southern versus northern Utah from data we gathered from publicly available information on municipality websites. Average prices do appear to be higher in southern Utah than northern Utah, which is a logical result given that most municipalities in the southern half of Utah are much drier and hotter than municipalities in the northern half of Utah. However, average rates after tiered pricing do not appear to have increased. Given that these distributions appear to be strikingly similar, despite the fact that there is implied temporal variation in real terms, and many more observations in 2022, these data do not suggest that municipal pricing policies have increased monthly average water rates faced by consumers over time.

A variety of additional descriptive figures and summary statistics are provided in Appendix C. Figure C.1 shows the trend in average consumption juxtaposed against average population and shows analogous variation to Figure 2. Figure C.2 shows the trend in total annual consumption juxtaposed against the trend in average consumption per capita, which shows that while total water use is increasing over time, consumption on a per capita basis seems to be getting more efficient – an idea which is corroborated by the trend in the median in Figure 2. In 2022, the total water used for residential culinary uses was 329,437.2 acre-feet while average consumption per capita was 52.98 thousand gallons per year. These trends and figures are comparable to data reported nationally by the USGS in 2015, which show that arid western states generally have high water use per capita (Dieter and Maupin 2017).

Figures C.3 shows variation in trends in annual municipal water consumption conditional on having tiered water pricing juxtaposed against the average year of adoption, which is 2005. This figure suggests that on average, municipalities with and without tiered pricing do tend to move in comparable trends, though level differences can be large in terms of total water use (less so for consumption per capita), and average trends become more comparable as more municipalities are reporting by the 1990s. Among treated units the average total water use and use per capita over 1990-2022 respectively are, 3,096.88 acre-feet and 59.35 thousand gallons per capita.

Figure C.4 shows variation in average seasonal precipitation and temperature at the municipal level. This figure shows averages across the monthly series we use as control variables. While there is significant variation, these trends and levels confirm what is generally known about seasonal precipitation and temperature in Utah: winter is the coldest season and has the most precipitation, summer is the hottest season with the least precipitation, spring tends to be a bit rainier than fall, and temperatures can be comparable in spring and fall. On average, there are no indications of significant departures from standard seasonal variation over 1980 - 2022, though this does not preclude potential for climatic variation to be exhibited at the tails or in other measures.

Additional data that round out summary statistics include: Tables C.1 and C.2 and Figures C.5 and C.6. Table C.1 provides general summary statistics from UDWRi-WR data for the year 2022, and data we collected on culinary water prices in 2022. Table C.2 provides summary statistics from important variables captured in the *Utah Culinary Water Pricing Survey*. Figures C.5 and C.6 respectively show barplots depicting the distribution of motivations for adopting tiered water pricing and the proportion of residents with access to secondary water for irrigation (e.g., generally non-potable alternatives sources for irrigation).

While our study is not designed to study the specific effects of SB28, which ostensibly requires municipalities to have a tiered pricing policy, the descriptive analysis here suggests this piece of legislation may have had limited influence on adoption or in increasing the costs of water culinary water consumption. Generally, municipalities seem to have been adopting tiered pricing policies widely at different periods of time since at least the 1980s, but the costs of culinary water over time in real terms do not seem to be increasing regardless of tiered pricing adoption. Although total water use is steadily increasing over time with population, on a per capita basis Utahns seem to be using water more efficiently. The extent to which having a tiered pricing policy at the extensive margin has had an influence on consumption remains an open question.

4 Econometric Models

The question we seek to answer is whether having an increasing tiered pricing structure for residential culinary water at the extensive margin has any effect on water consumption. In other words, is simply having such a pricing structure sufficient to induce a change in consumption? To test this idea we leverage annual observations on water use from UDWRi-WR data, monthly weather observations for each year, and observations on the staggered adoption of tiered water pricing for residential culinary water at the municipal level from the *Utah Culinary Water Pricing Survey*. Using this data, we apply the two-stage DiD estimator from Gardner et al. (2025), which is robust to heterogeneity in treatment timing and treatment effects and permits use of time-varying exogenous covariates in the first stage, which is estimated using the untreated observations, while the second stage is estimated on all observations. This two-stage estimator is captured in the equations below.

First stage equation:

$$Y_{mt} = \boldsymbol{X'_{mt}\theta} + \lambda_m + \alpha_t + \eta_{mt} \tag{1}$$

Second stage equation:

$$\tilde{Y}_{mt} = D_{mt}\beta + \varepsilon_{mt} \tag{2}$$

In equation 1, Y is a measure of water consumption (e.g., total consumption or consumption per capita) in municipality m in year t, $\boldsymbol{X'}$ is a vector of monthly average temperature and precipitation that occur in year t for municipality m, η_{mt} is the first stage error term, $\boldsymbol{\theta}$ is a vector of coefficients to be estimated, and λ_m and α_t are unit and period fixed effects to be estimated.

In equation 2, $\tilde{Y}_{mt} \equiv Y_{mt} - \mathbf{X}'_{\mathbf{mt}}\widehat{\theta} - \widehat{\lambda_m} - \widehat{\alpha}_t$, is the residualized outcome evaluated over all observations using the aforementioned parameters estimated from equation 1. D_{mt} is a dummy variable capturing the presence of tiered water pricing at the extensive margin, β is the parameter of interest, the average treatment effect on the treated (ATT) for the extensive margin effect of tiered water pricing, and ε_{mt} is the second stage error term. To estimate period-specific ATTs (i.e., dynamic treatment effects) and assess satisfaction of conditional parallel trends, dummy variable D_{mt} is replaced by a vector of event time dummies capturing periods prior to adoption, and the initial and post periods of adoption. Conditional on satisfaction of conditional parallel trends, this identification strategy can correctly identity the overall ATT (a weighted average of all post-treatment period-specific ATTs) and respective dynamic treatment effects. If conditional parallel trends are not satisfied, treatment effect estimates may be biased.

In Utah, since SB28 seems to have had limited influence in increasing adoption of culinary tiered water pricing, adoption seems to potentially be endogenous. For credible identification with the two-stage estimator from Gardner et al. (2025), this raises the importance all the more for credible satisfaction of conditional parallel trends. To address these challenges as best we can, we undertake a number of robustness checks. First, we undertake estimations of a variety of alternative specifications, including standard two-way fixed effects (TWFE) DiD for comparison, and variation in the number of controls that we incorporate. Second, we estimate models with alternative versions of our outcome of interest (both 'raw' and imputed/winsorized versions), including total annual consumption and consumption per capita with alternative weighting schemes.[3] Third, given the unbalanced nature of our panel, we undertake estimations on different subsets of the data to understand potential sensitivity to panel composition. Fourth, to address potential issues with satisfaction of conditional parallel trends, we implement the methods from Rambachan and Roth (2023), which adjust estimated confidence intervals to account for potential violation of parallel trends in the post-treatment period.

5 Results

5.1 Extensive margin effect of tiered culinary water pricing

Overall ATTs from equation 2 are presented in Table 1 for two alternative outcomes of interest, estimated on a subset spanning 1990–2022. The first specification uses total municipal water use (acre-feet) as the dependent variable and is estimated using municipal population weights. The second specification uses municipal water use per capita (thousands of gallons per resident) and is estimated without population weights. Weighting the total water use specification by municipal population places greater emphasis on municipalities where most residents are concentrated, yielding a population-weighted estimate of the average effect on total municipal water demand. The unweighted per-capita specification gives each municipality equal influence, regardless of population size, and is interpreted as the average effect on municipal water-use intensity. Taken together, the two specifications distinguish changes in total water demand at the municipal level from changes in per-capita water-use intensity.

We favor the 1990–2022 subset because it is more balanced than the longer 1980–2022 panel while maintaining a larger set of pre-treatment observations compared to shorter panels

[3] A standard TWFE DiD would be as follows, $Y_{mt} = D_{mt}\delta + \boldsymbol{X'_{mt}\gamma} + \lambda_m + \alpha_t + \nu_{mt}$, with δ capturing the treatment effect of interest. The caveat with TWFE DiD with staggered treatment timing and potential for treatment effect heterogeneity is severe bias and potentially even sign-flips from the true causal effect of interest (Roth et al. 2023).

(e.g., 2000–2022).[4] This subset and all other preferred estimations apply simple imputations to isolated, non-consecutive instances of missing water use and population, neither of which varies substantially from year to year, and we winsorize extreme outliers either by applying the aforementioned imputation technique, or by setting such observations to missing if this technique is not viable. Our preferred specifications therefore mitigate the influence of missingness and extreme outliers while retaining municipalities with observations of pre- and post-treatment outcomes, clearly documented adoption histories of tiered pricing, and locally provided water service. Municipalities whose water is provided by an outside entity, and all always-treated municipalities, are excluded from preferred models.[5]

The point estimates in Table 1 indicate that on average, adoption of tiered culinary water pricing reduces total municipal water use by approximately 1,300-1,400 acre-feet per year, and it reduces per capita use by approximately 4 thousand gallons per year. At the weighted municipal population average over the 1990-2022 subset of 129,716.3 residents, the per capita estimate scales in a fairly consistent manner to approximately 1,600 acre-feet per year.[6] However, while these estimates are suggestive of a decline in water use, all point estimates are statistically insignificant, meaning that we cannot reject the null hypothesis that the extensive margin effect of adopting tiered culinary water pricing is zero. Event studies in Figure 5, estimated using the corresponding first stage captured in column 5 of Table 1, provide credible empirical support for satisfaction of conditional parallel trends for both estimations. Both show evidence that most pre-trend coefficients are statistically insignificant, there is no evidence of systematic pre-trend movements in a particular direction,

[4]Specifically, the 1990–2022 subset contains 78% of the municipality-year observations that would be present in a fully balanced panel of 77 municipalities, whereas the 1980–2022 subset contains 66% of the municipality-year observations that would be present in a fully balanced panel of 79 municipalities.

[5]Although 94 municipalities responded to whether they have tiered water pricing, some of these municipalities did not have sufficient data for staggered DiD estimation. Municipalities are excluded for three primary reasons: (i) they are always treated (depending on the period analyzed); (ii) they are not always treated but lack pre-treatment outcome data; or (iii) the *Utah Culinary Water Pricing Survey* indicates that water service is provided in full or in part by an outside entity, or the municipality did not report whether it employs tiered pricing (Brighton, Draper, Farr West, Marriott-Slaterville, and West Haven).

[6]1 acre-foot equates to 325,851.43 gallons. Thus (4,000 * 129,716.3) / 325,851.43 = 1,592.337 acre-feet.

and point estimates are near, or circle around, zero. Exceptions to this are clustered around the earliest event time periods, which are more imprecisely estimated due to smaller cohort samples in these periods – likewise with later treatment periods.

This overall finding is intuitive based on economic theory, longstanding empirical work, and other components of our analysis. First, a finding that a switch from a uniform or flat rate to an increasing tiered rate does not translate into a statistically significant decline in water use, no matter the potential price information this may convey to consumers, would not be surprising if the effective price after a policy change remains roughly the same or even marginally higher. The basic reasoning for this is the longstanding empirical evidence that culinary water demand is highly price inelastic. The descriptive analysis captured in Figure 4 that average tiered rates seem to not have changed in real terms after the policy change is consistent with this reasoning. Second, additional supporting evidence for this interpretation comes from the corresponding first stage results to the estimations captured in Table 1, which sequence increasing seasonal weather variation (Appendix D, Tables D.1-D.2) and analogous estimates made on the full available sample over 1990-2022 (Appendix D, Table D.3). These respective tables show that fixed effects explain most variation in these measures of water use and monthly weather variation is largely statistically insignificant. While a more elaborate study of seasonal weather distributions might show more notable relationships between annual water use and monthly weather variation, this result is intuitive for culinary water demand even if outdoor use is a fairly sizeable proportion of annual use. For example, automatic sprinkler systems and stable water pricing for the average consumer may offer ample incentive for consistent use levels regardless of weather conditions.

Looking more closely at effect sizes, the respective point estimates appear modest in economic terms, even abstracting from their lack of statistical significance. Among treated municipalities included in the estimation sample in Table 1, total residential culinary water use in 2022 was 170,694.7 acre-feet and average per-capita use was 43,763.24 gallons. The magnitude of the estimated reduction, 1,350 acre-feet, represents approximately 0.80% of total 2022 annual use among treated municipalities. On a per-capita basis, however, the magnitude of the estimated reduction, 4,000 gallons, represents approximately 9% of average 2022 per-capita use.

5.2 Robustness checks

We implement a number of robustness checks to assess the strength of our results, which are provided in Appendix C. First, we look at estimates from TWFE-DiD, and, using our preferred two-stage DiD estimator on the 1990-2022 subset, we implement estimations using alternative weighting approaches and the raw consumption data. These respective results are featured in Tables D.4-D.6 in Appendix D. Estimates from TWFE-DiD offer confirmation on the value of using a staggered DiD estimator in that estimates for weighted total use are positive and smaller in magnitude, while unweighted per capita estimates are negative and larger in magnitude. Both respective estimations are also statistically insignificant. Estimations using alternative weighting approaches yield estimates of the opposite sign and differing magnitudes, but respective estimates remain statistically insignificant. Finally, estimates using the same specifications and weighting shown in Table 1 but estimated on the raw consumption data are of the same sign shown in Table 1 but smaller in magnitude.

Second, we implement estimations on an alternative version of our panel that extends from 1980-2022. In this regard, we implement estimations on the 1980-2022 subset that mimic our preferred estimations featured in Table 1 (i.e., the same approach to missingness, extreme outliers, weighting etc.) as well as estimations on the 1980-2022 subset on the raw consumption data. Respective overall ATTs and event studies are featured in Tables D.7-D.8 and Figures D.1-D.2. These estimations have two more unique municipalities ($n = 79$) and a larger number of observations, yet greater panel imbalance. When estimated on the preferred version of the data that addresses missingness and extreme outliers, estimates remain similar in nature (i.e., negative and insignificant), though estimates for weighted total use are larger by roughly 500 acre-feet, while unweighted per capita estimates are sometimes positive, and negative estimates are smaller in magnitude. Respective estimates on the raw consumption data are more comparable for weighted total use, but per capita estimates are now positive, though both remain statistically insignificant. Notably, event studies for these respective estimations continue to offer credible support for satisfaction of conditional parallel trends. The main differences are that there is some increased imprecision in early and later event periods (logical with even greater panel imbalance), and generally greater imprecision when missingness and extreme outliers are not addressed.

Finally, we study alternative confidence intervals following Rambachan and Roth (2023), which account for potential violation of parallel trends in post-treatment periods, with a focus on specifications in column 5 of Table 1. Specifically, we use the "relative magnitude" approach, which uses the maximum observed deviation M from parallel trends in the pre-treatment period to bound potential post-treatment deviations from parallel trends to generate alternative confidence intervals that account for such deviations. These methods do not implement alternative point estimates. Intuitively, since our core result is a null finding and this approach generally produces larger confidence intervals, this method does not alter our core result. The primary value is rather an exercise in considering the extent to which alternative confidence intervals might suggest potential for economically meaningful effects. Respective figures are shown in Appendix D in Figures D.3-D.4. The primary insight that comes from this analysis is that larger and more economically meaningful post-treatment reductions in water use are indeed possible, but the symmetry of the respective adjusted confidence intervals also suggests potential for increased water use.

Taken together, the main takeaway is that our primary result is robust to these additional analyses. None of the respective estimations offer counter-evidence of our overall finding of a null extensive margin effect and alternative versions of event studies continue to lend support for our identification strategy.

6 Conclusion

The core question we seek to answer is whether tiered culinary water pricing has a measurable effect on water conservation at the extensive margin. In an intuitive sense, this question equates to asking: Is the policy enough? In settings with a conservative approach to regulation, such as the State of Utah, this question is useful to answer and in fact highly policy relevant. Indeed, in 2016 the Utah legislature passed SB28 which requires tiered pricing for municipal culinary water use with no penalty for non-compliance or requirements mandating relative aggressiveness of said policies. Assuming the intention behind such policies is to price water more appropriately and to incentivize conservation without being excessively restrictive to local jurisdictions in how they accomplish such goals, the effective hope and/or assumption behind such a law is that the policy itself might be enough.

Our findings suggest that simply having an increasing tiered pricing policy for water is an insufficient condition for inducing meaningful conservation. Using data spanning 1980-2022 on annual municipal water use from UDWRi-WR and data on the history of adoption of tiered pricing over time from the *Utah Culinary Water Pricing Survey*, which we implemented among municipal water managers in Utah, we find that the extensive margin effect of tiered water pricing is negative in sign (suggesting some potential for conservation), but the effect is statistically insignificant. While this does not amount to a direct test of SB28, our empirical tests equate to a test of the implied idea behind SB28 and analogous legislation. Moreover, as our analysis suggests SB28 has likely had limited influence on the rate of adoption of tiered pricing over time, the cumulative evidence does not suggest that such comparatively light-handed efforts at regulating water pricing and use do much to incentivize conservation.

One limitation of our analysis is that we are not able to implement tests of the effectiveness of tiered water pricing in Utah at the intensive margin. The available data are insufficient for this task as respective tests would require detailed data for many municipalities over long periods of time on dimensions of the intensity of application of the policy (e.g., number of tiers, average prices, or other measures of policy aggressiveness). We hasten to note that our analysis does not preclude the potential for tiered pricing in Utah to be effective at the intensive margin, and it is possible that the observed improvements in water use efficiency (e.g., declining per capita use levels over time) may result in part from effective implementation at the intensive margin and/or from some combination of existing price- and non-price tools. With an effort to enhance data collection and new efforts to gather hard-to-collect historical data on pricing and water use, abundant opportunities exist to replicate and/or extend our work in other settings.

For states and communities like Utah, however, our findings present clear cautions. If policy makers choose to adopt light-handed approaches to policy that nudge users towards adoption of a particular policy without adequate consideration for the underlying economics of the resource, the available evidence suggests the returns may be few and far between. In the case of culinary water demand, the core underlying economic reality is the highly price inelastic nature of demand. In such settings, economic theory and longstanding empirical work in water economics suggests that behavior will only change with noticeable increases in price levels sufficient to overcome stubborn demand. To better understand the price increases required to accomplish desired use levels, credible empirical analysis using modern econometric methods of local demand elasticities would be a worthwhile investment. Armed with such knowledge, policy makers can better understand the price levels required to accomplish conservation goals. Absent that information, getting the intensity level of the policy right can be a difficult exercise.

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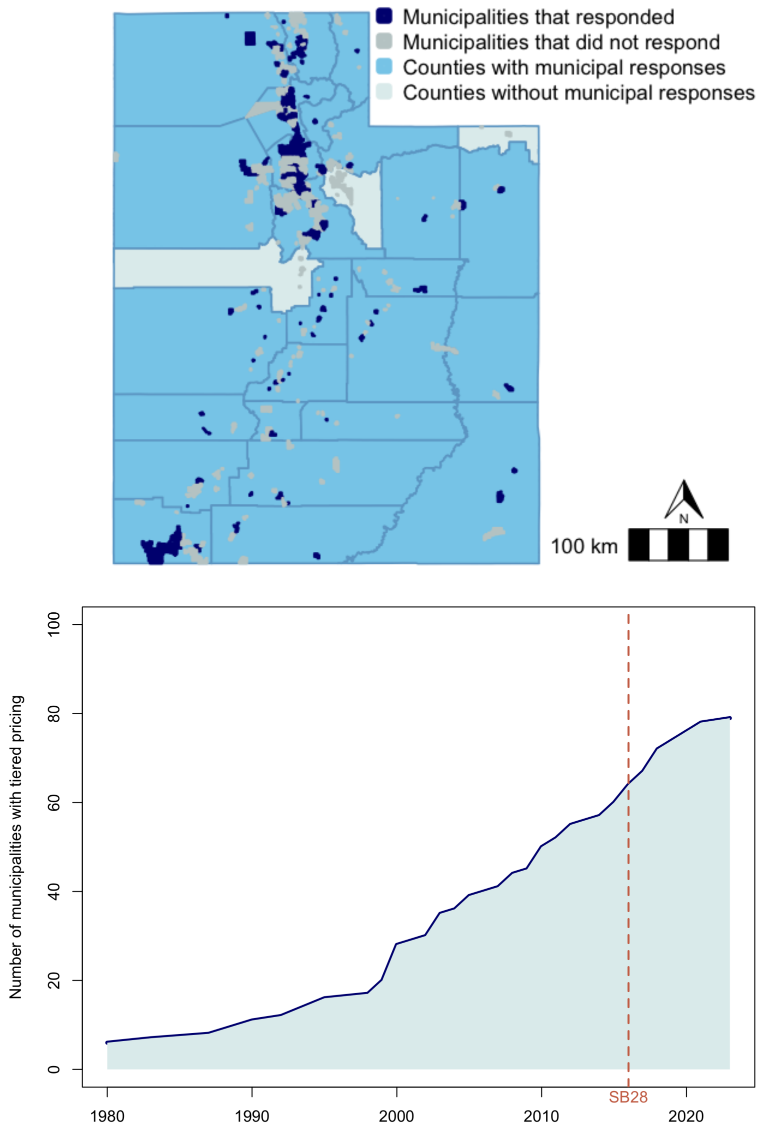

Figure 1: Top panel: Spatial distribution of municipal responses to the *Utah Culinary Water Pricing Survey*. Bottom panel: Out of 94 municipalities that reported whether they had tiered pricing in the *Utah Culinary Water Pricing Survey*, 83 indicated that they have tiered pricing, but only 79 of these reported the year when tiered pricing was adopted in their municipality.

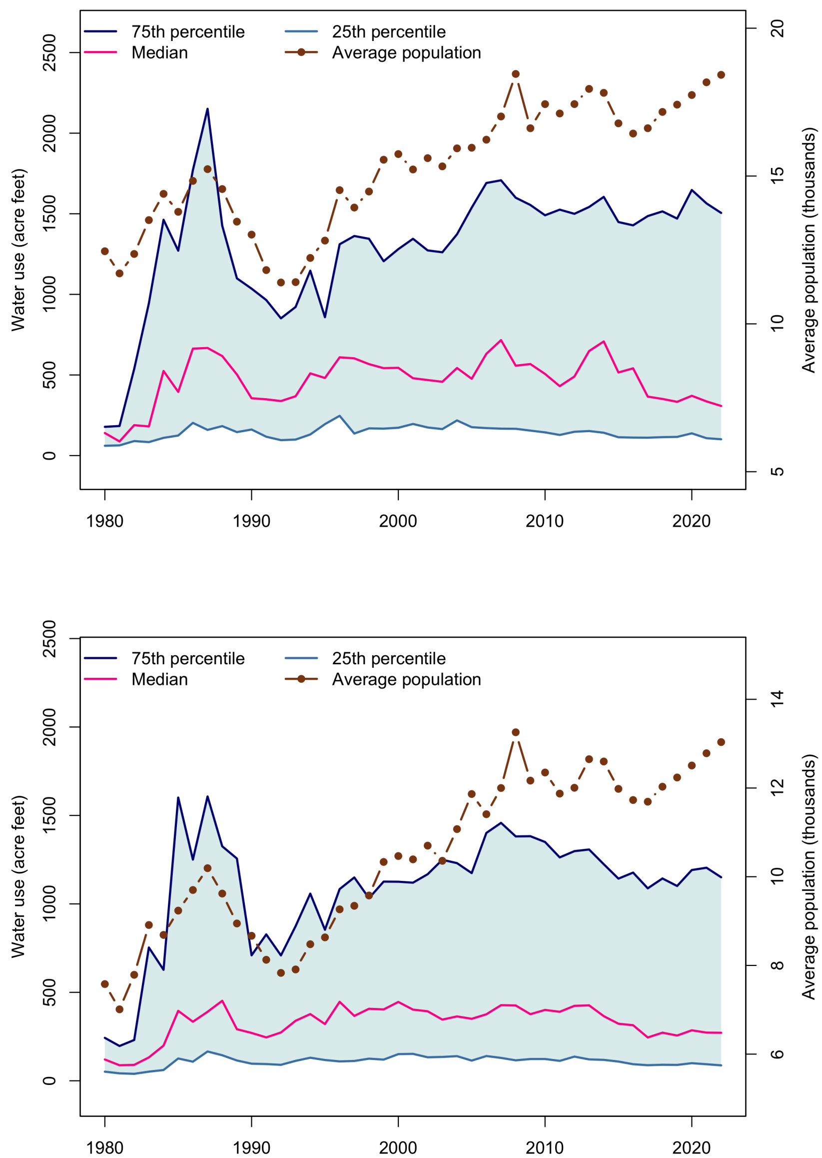

Figure 2: The distribution of residential culinary water consumption and average population from 1980 - 2022. Top panel: the distribution among municipalities captured in the in *Utah Culinary Water Pricing Survey*. Bottom panel: the distribution among the 242 unique municipalities captured in the available UDWRi-WR data.

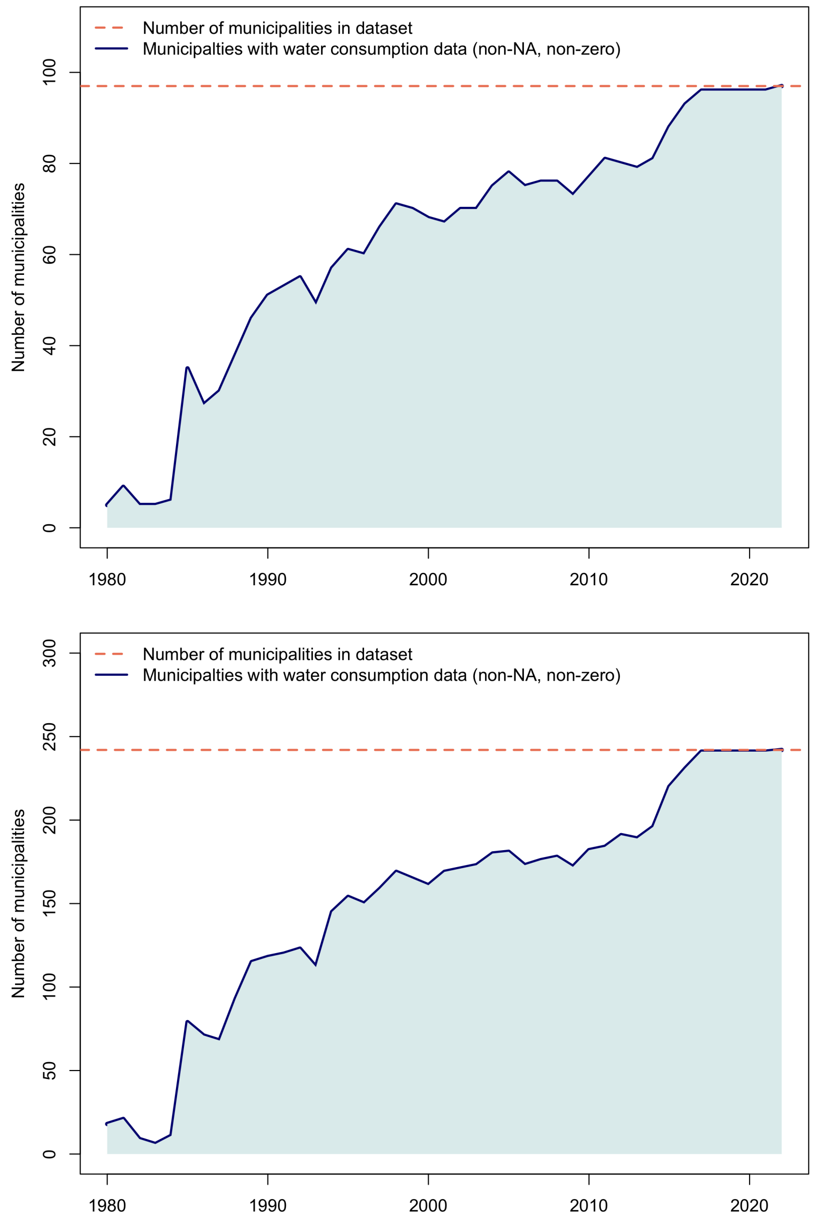

Figure 3: The number of municipalities with water consumption data over 1980 - 2022. Top panel: the distribution among municipalities captured in the in *Utah Culinary Water Pricing Survey*. Bottom panel: the distribution among the 242 unique municipalities captured in the available UDWRi-WR data.

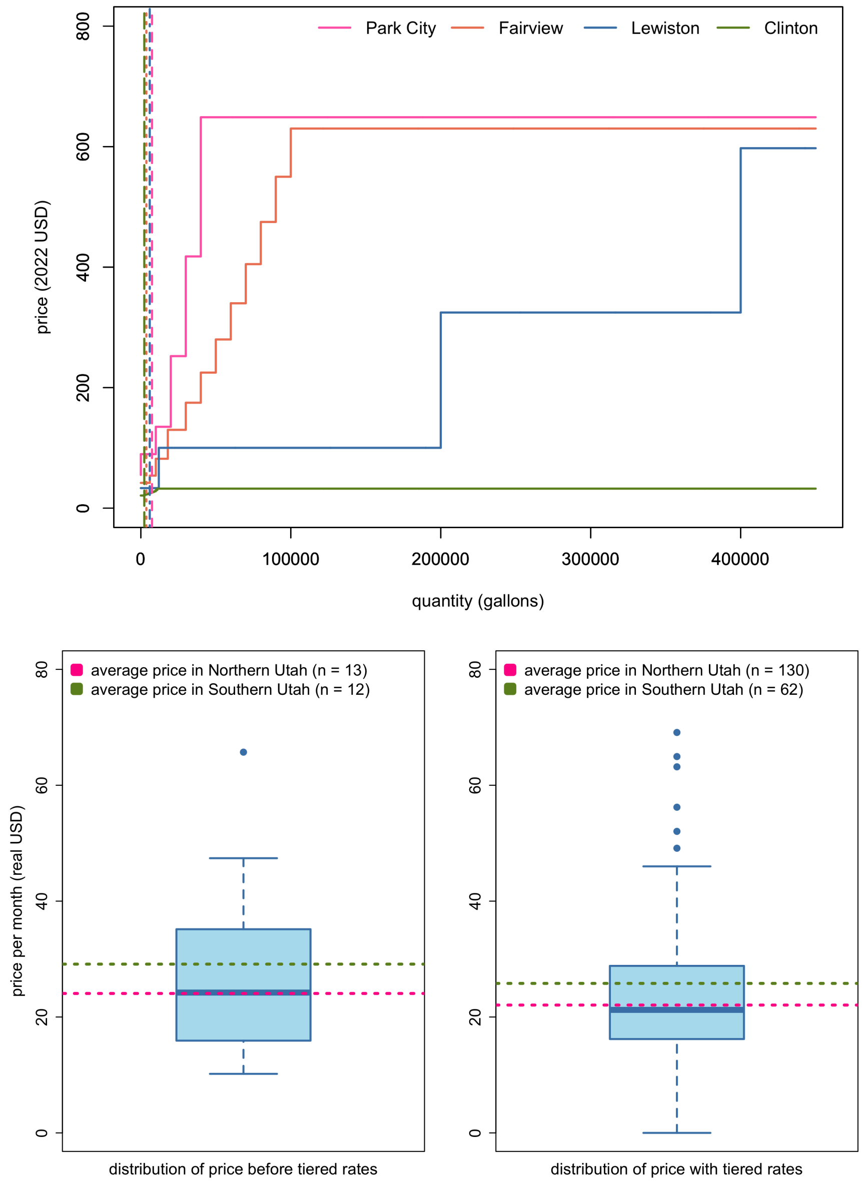

Figure 4: Top panel: Examples of municipal increasing block rate structures in Utah in 2022 (Park City, Fairview, Lewiston, and Clinton). Also depicted are vertical lines, which depict estimated monthly average consumption (i.e., dividing total annual consumption by 12 and dividing the result by the population in 2022). The implied average monthly price for water is found at the intersection of each step function. Bottom panel: Boxplots of estimated average real monthly water prices before and after the adoption of tiered water pricing. The leftmost boxplot is estimated from responses to the *Utah Culinary Water Pricing Survey* that provided information on water rates prior to tiered pricing ($n = 25$) with corresponding horizontal lines showing averages for Southern and Northern Utah; respective pre-tiered rates were either flat or uniform. The rightmost boxplot is estimated from data obtained from municipality websites in 2022 ($n = 192$) and corresponding estimates of monthly consumption (i.e., dividing total annual consumption by 12 and dividing the result by the population in 2022) with corresponding horizontal lines showing averages for southern and northern Utah. All rate information is adjusted to real terms using with 2017 base year (U.S. Federal Reserve Bank of St. Louis 2024). Averages for Northern Utah are calculated using municipalities from the following counties: Box Elder, Toole, Cache, Rich, Weber, Davis, Salt Lake, Utah, Summit, Daggett, Wasatch, Duchesne, Juab, Carbon, and Sanpete. Averages for Southern Utah are calculated using municipalities from the following counties: Millard, Sevier, Emery, Grand, Beaver, Piute, Wayne, Iron, Garfield, Washington, Kane, and San Juan.

Table 1: Overall ATT of extensive margin effect of having a tiered culinary water pricing policy over 1990-2022 estimated via two-stage DiD (Gardner et al. 2025).

Dependent variable: Total water use (acre feet)					
	(1)	(2)	(3)	(4)	(5)
Tiered pricing dummy (extensive margin)	-1,435.3	-1,420.2	-1,379.7	-1,343.9	-1,344.3
	(2,005.4)	(1,994.4)	(1,973.9)	(1,998.2)	(1,959.9)
Adjusted R^2	0.019	0.018	0.018	0.016	0.017
# Observations	1,985	1,985	1,985	1,985	1,985
Dependent variable: Water use per capita (thousands of gallons)					
	(1)	(2)	(3)	(4)	(5)
Tiered pricing dummy (extensive margin)	-4.4365	-4.1855	-4.0373	-4.1101	-4.5768
	(6.7943)	(6.5875)	(6.6730)	(6.6725)	(6.5856)
Adjusted R^2	0.003	0.002	0.002	0.002	0.003
# Observations	1,985	1,985	1,985	1,985	1,985
First stage specification parameters					
Municipality FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Summer covariates	N	Y	Y	Y	Y
Fall covariates	N	N	Y	Y	Y
Spring covariates	N	N	N	Y	Y
Winter covariates	N	N	N	N	Y

Notes: Results for two dependent variables are presented above with two different weighting strategies: 'Total water use (acre feet)' is weighted by population; 'Water use per capita (thousands of gallons)' is not weighted. Standard errors are in parentheses and clustered at the municipality level ($n = 77$ unique units). Significance codes: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

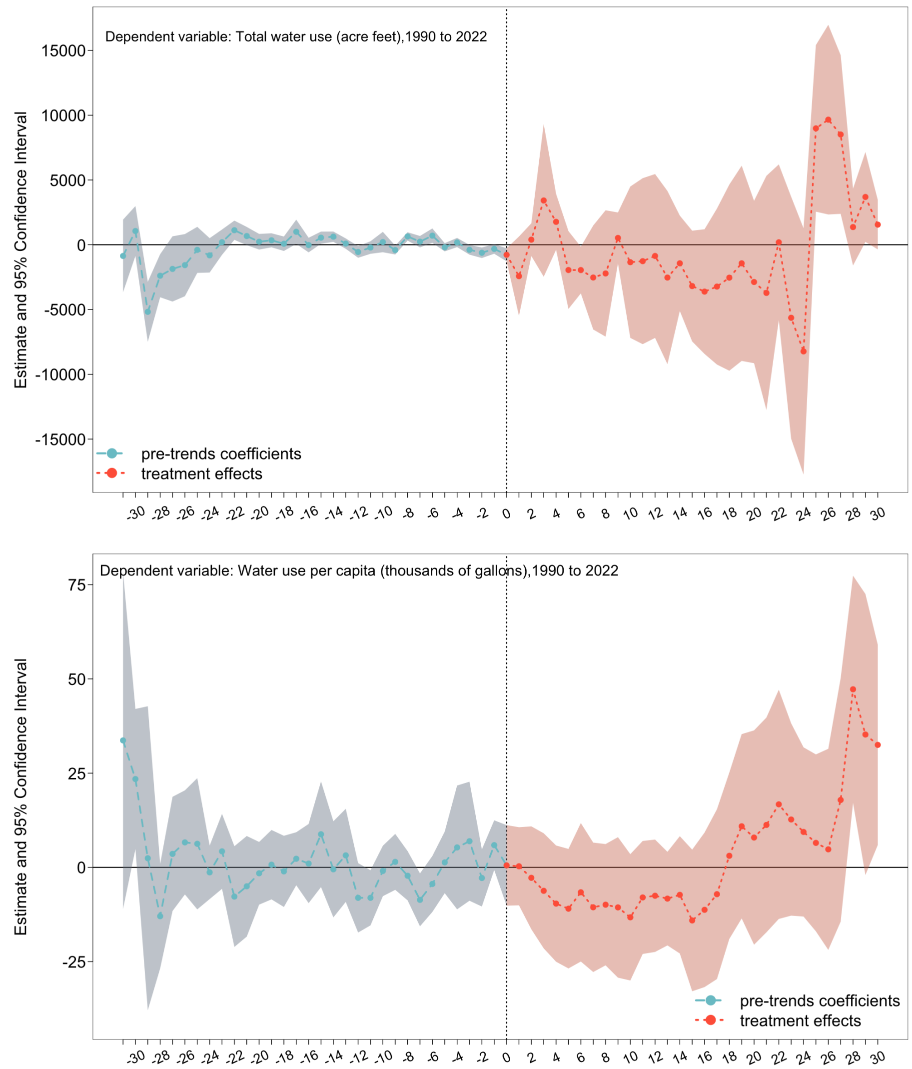

Figure 5: Event studies via Gardner et al. (2025) of the extensive margin effect of adopting tiered water pricing. Top panel: Event study for total water use (acre-feet) over 1990-2022 (population-weighted). Bottom panel: Event study for water use per capita (thousands of gallons) over 1990-2022 (not weighted).