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Understanding the Cost of Basic Drinking Water Services in the United States: A National Assessment

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ABSTRACT

The cost of basic drinking water services has implications for affordability, investment capacity, and public health. The fragmentation of drinking water services in the United States makes it difficult to reliably track and compare what customers pay for basic drinking water services. This paper uses a new, national dataset to examine the social, political, environmental, and institutional drivers of the cost of basic drinking water services, measured as the cost to households of 6000 gal of water per month. We find basic drinking water service costs vary widely across the United States. Costs are generally higher in smaller and more liberal cities and lower in places that rely on groundwater sources. Our findings provide a unique national perspective on variation in, and drivers of, the cost of basic water services and can inform efforts to improve the affordability, accessibility, and quality of drinking water services in the United States.

1 | Introduction

Safe, affordable drinking water is important for public health, community development, and well-being. Yet, water costs are rising faster than most other household expenses, including electricity, gas, and housing (Kane and Broaddus 2016). Between 2010 and 2018 alone, the cost of combined water and sewer rose by 80% in some US cities (Colton 2020). These increases can represent a significant burden for low-income households in particular and have generated renewed attention from policymakers, advocates, and scholars to the affordability of drinking water services. Analyses of single states and smaller sets of cities have shown the cost of water services in the United States is unevenly distributed (Butts and Gasteyer 2011; Teodoro 2019; Goddard, Ray, and Balazs 2021), but we lack a full understanding of this distribution and the factors that drive it due to the absence of comprehensive, accessible, and comparable water rates data in the United States.

We build on prior research by using the new municipal drinking water database (MDWD) (Hughes et al. 2022, 2023), which contains more than 2000 municipally owned and operated drinking water utilities to understand the distribution and drivers of the cost of basic drinking water services from a national perspective. The dataset is unique in compiling demographic, political, financial, and environmental information about a comprehensive set of municipal systems. We add to the MDWD information about the cost of basic drinking water services, equivalent to the cost to households of using 6000 gal of water per month (Teodoro 2018, 2019). We then use state-level fixed effects

Summary

- Our national assessment provides new insight into how and why the cost of water services varies in the U.S., helping illuminate important areas for future research and priorities for policymakers.

models to analyze the relationship between the cost of drinking water and the context and characteristics of municipalities. The findings provide new insight into how and why the cost of drinking water services varies in the United States, helping illuminate important areas for future research and priorities for policymakers.

2 | The Underpinnings of the Cost of Drinking Water Services

Drinking water services in the United States are provided by a range of utility types that include private companies, special purpose governments, and municipal governments. The focus of this paper is municipally owned and operated drinking water systems, which provide water for at least 40% of Americans (Hughes et al. 2023). The revenue available to municipal drinking water systems for spending and investing largely depends on the rates they charge their customers or the rates set for volumetric water use. Water rates—or the volumetric price of drinking water—are set by local governments and utility managers and reflect the cost of service provision incurred by the utility. Relatively flat federal and state investments in drinking water infrastructure over the past 40 years (CRS 2019) have not kept pace with increasing needs, placing a significant additional burden on municipal drinking water systems. Nearly 90% of drinking water capital projects are now funded from water service fees (U.S. EPA 2016). In addition to affecting revenue, water rates affect the affordability of drinking water services for residents. The cost to households of drinking water has increased faster than inflation and faster than most other municipal services. Absent policy change, drinking water costs to households are likely to increase further given the need to fix deteriorated infrastructure and make up for delayed maintenance and investment (American Society of Civil Engineers 2020), build resilience to climate change (Huang, Bixler, and Mo 2023, and address emerging contaminants.

We focus in this paper on the cost to households of basic drinking water services, rather than the affordability of those services, which requires a choice of denominator or other way of normatively interpreting the cost. For our purposes, cost to households is a valuable measure as it captures directly the differences households pay for the same level of service (e.g., volume of water) due to rate setting (i.e., price) decisions made by the utility and is subsequently more easily interpreted and comparable. As important as drinking water rate-setting decisions are, the fragmented nature of the water sector in the United States makes it difficult to use prices as a metric for tracking the patterns and trends in the subsequent cost of water services (Scott, Moldogaziev, and Greer 2018; Mullin 2020; Moldogaziev, Scott, and Greer 2023). Variations in administrative arrangements and data availability for drinking water systems further challenge efforts to comprehensively evaluate costs. In this article, unless specifically stated otherwise, we use the term "water costs" to refer to the water bills received by households, which reflect prices set to recover the cost to the utility of service provision.

Previous research on drinking water rates and affordability demonstrates both variations in water costs and problems with the affordability of drinking water services in the United States. In an analysis of reported water and sewer costs in Michigan, Butts and Gasteyer (2011) find that monthly water costs, or the amount households pay per month for water, ranged from $18.33 to $47.33. In another study of over 1300 water and sewer systems in Georgia, Arizona, Wisconsin, and New Hampshire, El-Khattabi et al. (2023) found median water costs for 4000 gal per month ranged from $23.00 to $33.00. In an analysis of 329 US drinking water utilities, Teodoro (2019) finds that monthly basic drinking water services (6200 gal) range from less than 5 to more than 30% of household income at the 20th percentile. Similarly, Goddard, Ray, and Balazs (2021) find that monthly water bills (at 4500 gal) range from $3.06 to $466 in California. Using survey data for 296 drinking water providers, Mack and Wrasse (2017) estimate that water bills (at 12,000 gal per month) are unaffordable (i.e., constitute more than 4.5% of median household income) for nearly 12% of US households and that the number could grow to 35% over the next 5 years. Teodoro and Saywitz (2020) found that the affordability of basic water services (6200 gal per month) has worsened for low-income households since 2017 and that the monthly cost of basic water services has increased on average by $3.23 per month between 2017 and 2019.

While somewhat fragmented—using different measures, outcomes, and geographic foci—prior studies of water costs and affordability in the United States point to meaningful variation and very uneven experiences of this variation. Considered collectively, this and other prior research indicate four potential drivers of drinking water costs: the fiscal condition of the municipality or water utility; community characteristics; organizational characteristics; and environmental conditions or risks.

2.1 | Fiscal Condition of the Municipality or Water Utility

Drinking water rate setting and revenue collection should reflect the cost of service provision including maintenance, investments, and debt payments (Pierce, McBride, and Adams 2022). Thus, we would expect a positive relationship between the cost and households of basic drinking water services, the amount of spending on the drinking water system, and the amount of debt associated with the drinking water system. However, there are several reasons why the relationship between the cost of basic water services and overall spending on the system may not be tightly correlated. Municipal drinking water systems make choices about how to distribute costs across industrial, commercial, and residential users and design rate structures. Two drinking water utilities making similar overall expenditures could choose to recoup those costs in very different ways. As discussed in greater detail below, municipalities also make decisions about the cost of their services, including whether and how to invest in infrastructure, that can be driven by a range of technical, regulatory, and political considerations. Municipal utilities also operate in more or less restrictive state fiscal policy environments. While drinking water revenue streams are typically protected from general municipal spending decisions, tied directly to water bills and reinvestment in the drinking water system, there are concerns raised periodically that municipalities use drinking water service funds to subsidize municipal general funds, exposing the drinking water system to fiscal pressures beyond its control (Pierce, McBride, and Adams 2022; Gibson 2022; Phinney 2023). Given these competing dynamics, we examine the relationship between overall spending on the drinking water system and the cost to households of basic water services, although with the expectation that they will be positively related.

2.2 | Community Characteristics

The size and socioeconomic characteristics of the community served by drinking water utilities may also influence the cost of drinking water services. For example, larger communities are likely to see lower drinking water costs (El-Khattabi et al. 2023) due to economies of scale involved in operating and maintaining drinking water systems (Carvalho, Marques, and Berg 2012). Similar patterns could be expected for more dense communities. In a study of Michigan households, higher costs to households of water and sewer services were found to be strongly associated with minority racial status (Butts and Gasteyer 2011), though this finding is not consistent across studies (El-Khattabi et al. 2023). Further examination of the relationship between race and cost of water with a larger, national dataset would therefore be valuable. Price increases can be politically highly salient (Hansen and Mullin 2022; Hughes 2019), so we may expect to see lower drinking water costs in communities with lower household incomes.

While we are unaware of studies examining the relationship between residents' political ideology and water costs or affordability, numerous studies have examined the relationship between ideology and local government policy decisions more broadly (Einstein and Kogan 2016; Tausanovitch and Warshaw 2013; Gerber 2013; Switzer 2019). In particular, Einstein and Kogan (2016) found that local governments with more Democratic residents had higher revenues and spending than Republican-leaning communities. Similarly, Tausanovitch and Warshaw (2013) found that cities with more conservative residents had more conservative policies overall and lower taxes and expenditures per capita. Similarly, studies of local government environmental policy found that governments are responsive to the political ideology of residents (Krause 2011; Deslatte and Feiock 2019; Switzer 2019; Gerber 2013).

With respect to water spending, it is reasonable to expect cities serving more conservative populations will have lower water rates and reduced spending on drinking water. Research has consistently found that conservatives and Republicans are less concerned with water infrastructure. Leiserowitz et al. (2011) found that while 70% of Democrats believed protecting local water supplies from global warming was important, this was true only for 48% of Republicans. Likewise, Vedachalam, Kay, and Riha (2014) found that conservative individuals were less likely to express concern with water infrastructure. Finally, Hansen and Mullin (2022) found that Republican local elected officials were less likely to be concerned with their local water infrastructure and more likely to state that they were concerned about making financial investments in their system, indicating less willingness to spend on drinking water. Lower spending should be reflected in lower water costs (though see our discussion of this relationship above).

2.3 | Organizational Characteristics of the Municipality or Water Utility

Beyond fiscal and demographic characteristics, there may be organizational features of municipalities that affect the cost of drinking water services. Larger city governments with more employees will cost more to run, which could be reflected in the water rate setting. Institutional structure can also play a role. The local government literature has long emphasized that governments with elected mayors are more likely to be responsive to political pressure and public opinion than those with appointed city managers (Carr 2015). Municipalities with an elected mayor may be more sensitive to potential public opposition to water rate hikes (regardless of infrastructural needs) (Hansen, Mullin, and Riggs 2020), and thus, we should expect to see municipalities with an elected mayor to have lower water rates (and subsequently lower water costs) than municipalities with other institutional arrangements. Utilities that purchase their water wholesale may require a more sophisticated organizational structure to procure, maintain, and manage these purchasing contracts and tend to be in better compliance with SDWA regulations, which may drive higher water rates. If drinking water systems struggle with regulatory compliance or have had recent health-related drinking water quality violations, they must remediate these issues which may drive higher rates as a result.

2.4 | Environmental Conditions or Risks Facing the Municipality or Water Utility

Finally, municipal drinking water systems operate in very different environmental conditions and face different challenges in ensuring safe and reliable drinking water supplies. We might expect drinking water systems in arid areas to have higher drinking water costs due to the need to invest heavily in water conservation measures while also supporting larger outdoor water use demand. Additionally, drinking water systems have access to more or less expensive water sources depending on their location. Surface water is more prone to contamination, resulting in higher costs and compliance steps for the utility compared to systems that use groundwater. Table 1 summarizes the potential drivers of drinking water costs and their expected relationship as well as the data sources used in the analysis.

3 | Methods

3.1 | Data Collection

We use the publicly available MDWD (Hughes et al. 2022, 2023), which is comprised of the *US municipalities with a population of 10,000 or more that own and operate a drinking water system*.

TABLE 1 | Expected relationships between the cost of basic drinking water services and fiscal conditions, community characteristics, organizational structure, and environmental risk. All variables are measured at the municipal scale.

Type of driver	Variable	Expected relationship to cost	Data source
Fiscal conditions	Revenue per capita	+	Government Finance Database
	Debt ratio	+	Government Finance Database
	Water utility expenditures	+	Government Finance Database
Community characteristics	% Black	+	American Communities Survey
	% Hispanic	+	American Communities Survey
	Population size	−	American Communities Survey
	Population density	−	American Communities Survey and US Census
	Median household income	−	American Communities Survey
	Conservative political ideology	−	Voters and Elections Science Team (VEST)
Organizational structure	Government size (FTE)	+	US Census
	Mayor form of government	−	ICMA/Census of Governments
	Purchased water dependence	+	EPA SDWIS
Environmental risk	SDWA violation	+	EPA SDWIS
	Aridity	+	Willmott and Feddema Moisture Index Archive
	Surface water dependence	+	EPA SDWIS

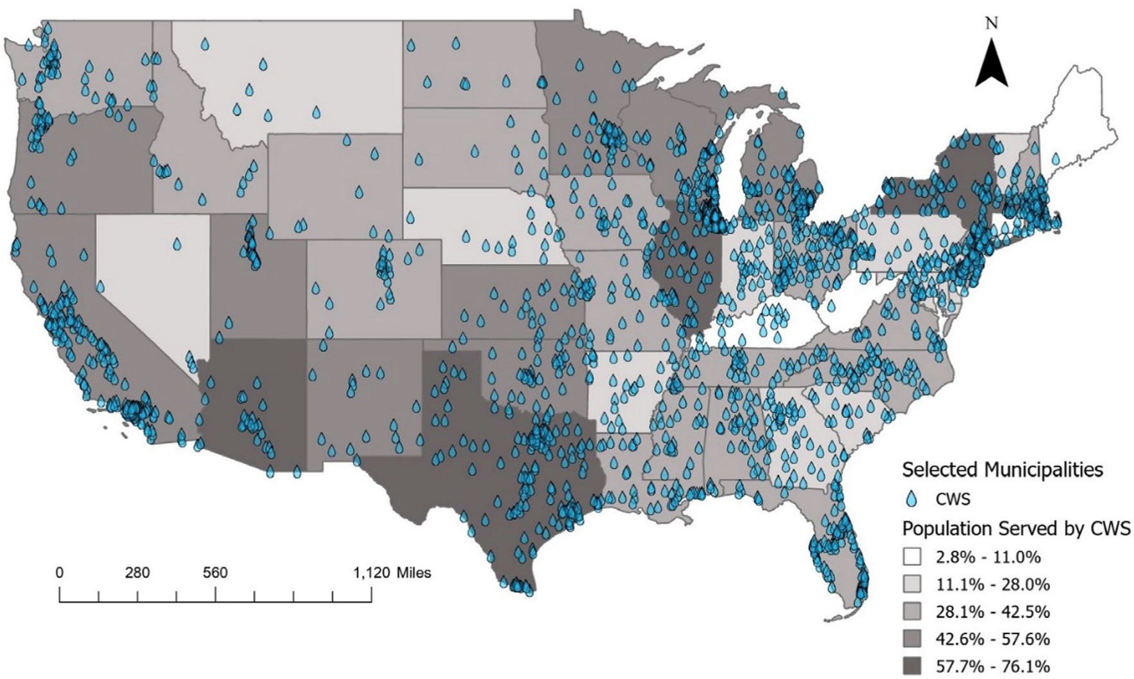

FIGURE 1 | Municipal drinking water systems in the contiguous United States.
Source: Hughes et al. 2022.

This database includes information for more than 2000 municipalities throughout the contiguous United States, as Alaska and Hawaii do not have municipally owned and operated drinking water systems in the conventional sense (Figure 1). For context, there are 23,800 publicly owned and operated water systems in the United States, though just 9% (2142) serve 88% of the

US population (Beecher 2013). The MDWD matches drinking water utilities with the municipalities they serve, allowing the integration of multiple disparate datasets. The pairings have been rigorously checked through both automated matching criteria and reviews by hand, including strategies to ensure that municipalities with fragmented drinking water service areas and multiple service providers are not included (see Hughes et al. 2022 for a more complete description of the dataset and its construction).

A team of six graduate and undergraduate students and three PIs then used internet searches to collect drinking water rates information for municipal drinking water systems in the MDWD over a period of 6 months, from November 2021 to May 2022. Using information posted on the city website or embedded in the municipal code, we recorded the most recently available drinking water rates information. In cases where no information about drinking water rates was publicly available, we contacted the utility directly by email or telephone. This produced drinking water rate information for 2161 municipalities. We used this raw information about the fixed charges and volumetric rates levied by the drinking water systems to calculate the cost of basic drinking water services, Water cost. We defined basic drinking water services as 6000 gal of drinking water per month, representing the volume required to meet the basic needs of a family of four (Teodoro 2019) or what the US EPA refers to as the "minimum sanitary requirement" (U.S. EPA 2016). Water cost is a direct reflection of what it would cost a household to use 6000 gal of water in 1 month given relevant fixed charges and volumetric rates. In cases where municipalities had different rates at different times of year, we defaulted to the most expensive scenario to capture the maximum number of households in that community that would pay for basic water services. Water cost is the main dependent variable in our analysis. We used additional variables from the MDWD (Hughes et al. 2023) and political ideology data from the VEST project (Warshaw and Tausanovitch 2022) to operationalize our explanatory factors in the following ways.

3.2 | Fiscal Condition of the Municipality or Water Utility

We operationalize the fiscal condition of the municipality or water utility as revenue per capita, drinking water utility spending per capita, and the city government's debt ratio. These measures, which provide information about a city's revenue stream and its broader financial position, have been found to perform well as predictors of financial emergencies and changes in service provision. Changes in revenue per capita are considered a good measure of the sustainability of a city's financial condition (Gordon 2018). Revenue per capita is also a clear manifestation of the broader economic conditions that lead to financial stress in city governments, such as a loss of population, declining home values, and rising poverty rates (Brookings Institution 2016). Both measures have been found to be significantly related to perceptions of financial stress by city government officials (Kim and Warner 2020). These data are all drawn from the MDWD (Hughes et al. 2022).

Therefore, we model the effects of the fiscal condition of the municipality as follows:

$$\begin{aligned} \text{WaterCost}_i = \beta_0 + \beta_1 \text{Revenue Per Capita} + \beta_2 \text{Debt Ratio} \\ + \beta_3 \text{Water Utility Expenditures} + u \end{aligned}$$

3.3 | Community Characteristics

We operationalize relevant community characteristics as the percent of residents that are Hispanic or Black, the log of the city's population size, population density, the community's median household income, and the estimated ideological preferences of residents (ranging from liberal to conservative). These political ideology estimates are generated from 18 large-scale surveys conducted between 2006 and 2021 and aggregated at the city scale using multilevel regression and poststratification (Warshaw and Tausanovitch 2022). As a sensitivity test, we also substituted the Democratic vote share from the 2016 presidential elections for the estimated ideological preferences, which includes a loss of 116 (about 5%) of observations. Our findings are robust to this change, with the effect sizes of race and ideology increasing slightly. Results from the alternate model specification can be found in Table A1 of the Appendix A.

Similar to the equation above, we model the effects of community characteristics as follows:

$$\begin{aligned} \text{WaterCost}_i = \beta_0 + \beta_1 \text{Perc. Black} + \beta_2 \text{Perc. Hispanic} \\ + \beta_3 \text{Population Size} + \beta_4 \text{Median HH Income} \\ + \beta_5 \text{Conservative Political Ideology} \\ + \beta_6 \text{CPopulation Density} + u \end{aligned}$$

3.4 | Organizational Characteristics of the Municipality or Water Utility

We operationalize the organizational characteristics of the municipality or water utility as the number of full-time equivalent employees (FTEs) per capita working at the municipal government and a dummy variable that captures whether the municipality is a mayor or manager form of government. Both variables were drawn from the MDWD and further documented there (Hughes et al. 2022). We drew data on whether the municipality purchases its water wholesale from SDWIS records.

We model the effects of organizational characteristics of the municipality as follows:

$$\begin{aligned} \text{WaterCost}_i = \beta_0 + \beta_1 \text{Government Size} \\ + \beta_2 \text{Form of Government} \\ + \beta_3 \text{Purchased Water} + u \end{aligned}$$

3.5 | Environmental Conditions or Risks Facing the Municipality or Water Utility

We operationalize environmental conditions or risks as a set of variables that include the drinking water's primary (though

TABLE 2 | Descriptive statistics of variables used in analysis. $n = 2119$.

Variable	Description	Mean	Min	Max
Water cost	Cost of using 6000 gal/ month, in dollars	$38.60	$5.00	$163.40
Fiscal condition				
Revenue per capita	Per thousand dollars, adjusted for inflation	$5723.60	$117.10	$32,526.50
Debt ratio	Total outstanding debt/total revenue, adjusted for inflation	1.0	0.0	37.5
Water utility expenditures	Per thousand dollars, per capita, adjusted for inflation	$535.40	0.0	$6993.60
Community characteristics				
Percent Black	Percent of population that identifies as Black	11.5	0.0	94.3
Percent Hispanic	Percent of population that identifies as Hispanic	16.2	0.0	98.8
Population size	Logged total population	10.4	9.0	16.0
Median income	Median household income in thousand dollars	$60.60	$16.30	$250.00
Conservative ideology	Estimated political ideological preferences. Higher values indicate more conservative	0.0	−0.7	0.6
Organizational structure				
Government size	Full-time employees per capita	11.2	0.0	91.3
Form of government	Dichotomous variable where a municipality with a Mayor is represented as a "1" and other governmental forms are represented as a "0"	0.4	0.0	1.0
Purchased water	Binary variable indicating whether any water is purchased (1 = purchased, 0 otherwise)	0.3	0	1
Environmental risk				
SDWA violations	Binary variable indicating whether system incurred health-based violation(s) over the last 5 years	0.2	0	1
Aridity	Annual average value of moisture index; lower value indicates more arid conditions	0.2	−1.0	0.9
Surface water	Binary variable indicating whether the system uses groundwater (1 = surface water, 0 = groundwater)	0.7	0	1

not necessarily exclusive) water source (binary variable indicating primarily ground or surface water); a measure of whether the utility has had a health-based violation from the US EPA in the past 5 years using SDWIS records and using Willmott and Feddema's Moisture Index (Willmott and Matsuura 2018; Willmott and Feddema 1992), constructed an average annual moisture index value for 2017.

We model the effects of environmental conditions as follows:

$$\text{WaterCost}_i = \beta_0 + \beta_1 \text{Purchased Water} + \beta_2 \text{SDWA Violation} + \beta_3 \text{Aridity} + u$$

We estimate the following linear regression model using OLS in Stata version 16. Robust standard errors corrected for clustering by state are implemented for all models. Although the results from the individual model runs contribute valuable information in understanding how the individual variables influence water costs, our primary interest is in evaluating the comprehensive effect of the explanatory variables on water cost. We present the combined model equation as follows:

$$\text{WaterCost}_i = \beta_0 + \beta_1 \text{Fiscal Conditions}_i + \beta_2 \text{Community Characteristics}_i + \beta_3 \text{Organizational Structure}_i + \beta_4 E\text{nvironmental Risk}_i + \text{State}_s + \varepsilon_{is}$$

State_s represents state-level fixed effects, which account for the fact that state governments may impose unique conditions on public service provisioning and drinking water rate setting. We used state fixed effects regression modeling to estimate the relationship between our predictors and the cost of basic drinking water services for each of the individual model runs and when evaluating the combined model. As a sensitivity test and recognizing the potential for regional effects on CWS and water governance, we repeat our analysis using the 10 EPA regional offices as a fixed effect. The EPA created these Standard Federal Regions to facilitate operations with local and state governments and for closer coordination with other federal agencies.

The central findings for the individual and combined model runs, presented in Table A2 in the Appendix A, are robust to this specification.

Finally, ε_{is} denotes the regression error term.

4 | Results

We used descriptive statistics to understand the distribution of drinking water service costs in the United States (Table 2). The cost of basic drinking water services (6000 gal per month) in the United States ranges from $5 to $163.40, with an average value of $38.60 (Figure 2). For a household with a single breadwinner working the maximum 40 h a week earning the federal minimum wage ($7.25/h), the average cost is approximately 3.3% of gross monthly income.

Table 3 presents the results from individual (columns 1–4) and combined (column 5) state fixed effects regression models. We find that, overall, each model contributes modestly to explaining the full variation in the cost of basic drinking water services. Moving from the individual model runs to the combined model run (column 5), we find an improvement in model fit, with the combined model explaining 26.7% of the variation in water costs.

The fiscal condition model shows that the strongest fiscal predictor of the cost of drinking water services is total expenditures per capita. However, the effect is relatively small. As expected, the coefficient on debt ratio is positively signed, suggesting that water utilities carrying higher debt relative to total revenue have higher water costs. We fail to observe a relationship between a municipality's total revenue per capita and the cost of basic water services.

The community characteristics model shows that larger communities pay less for basic drinking water services. The coefficient for both percent Hispanic and percent Black residents is negative, and there is a statistically significant, negative relationship between the percent Hispanic residents and the cost of basic drinking water services. More liberal communities pay more for basic drinking water services. We find no relationship between median household income and the cost of water.

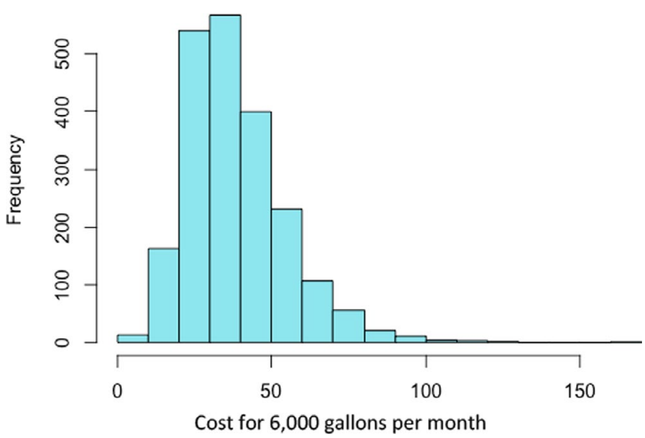

FIGURE 2 | Distribution of basic drinking water service costs.

The organizational structure model shows that municipalities with more employees per capita charge more for basic drinking water services. Mayor-led municipalities charge less for basic drinking water services. Municipalities that rely on purchased water have higher water costs.

The environmental risk model shows evidence that cities in arid areas have higher basic water service costs. We find no evidence that systems with recent SDWA violations charge more for basic drinking water services. Municipalities with surface water supplies tend to charge more for basic drinking water services.

The combined model (Column 5) reveals how these variables collectively contribute to variations in the cost of basic drinking water services. Figure 3 shows the coefficient estimates and 95% confidence intervals for these variables. We find a strong relationship between a municipality's debt ratio (its debt burden relative to its revenue) and the cost of drinking water services. This reflects the relationship between capital needs and investment and recouping those costs through rate setting. There is a persistent positive relationship between the amount of money a municipality or drinking water utility spends on its system and the amount it charges for basic services; however, the effect on cost remains small. Increasing the per capita water utility expenditures by $10,000 only increases the cost of basic water services by $0.05.

We find that the cost of drinking water services is overall lower in communities with larger Hispanic populations. Larger communities consistently pay less for drinking water services. Contrary to our expectations, we find a small but significant relationship between population density and the cost of basic drinking water services. We also find a significant relationship between conservative political ideology and the cost of water services, indicating that more conservative communities tend to pay less for monthly water services.

Our combined model shows that communities relying on surface water and purchased water pay more for drinking water services. Indeed, we find that a switch from ground to surface water is strongly and significantly associated with a $5.50 increase in the average cost of water and utilities that purchase water see a $2.86 increase in the average cost of water.

5 | Discussion

Drinking water services are central to public health and a core responsibility of many local governments. Understanding the distribution of the cost of these services between communities and the correlates of these costs is important for informing policy choices and scholarship on rate setting and affordability. However, large-scale assessment of the cost of basic drinking water services in the United States, and examination of a wide set of potential drivers, has been challenged by a lack of comparable and readily available, accessible data. In this study, we used a large, novel dataset to analyze the cost of basic drinking water services for more than 2000 US municipalities.

We find that the monthly cost to households of basic drinking water services varies significantly between communities,

TABLE 3 | Results from individual and combined state fixed effects models.

	(1) Fiscal	(2) Community	(3) Organization	(4) Environmental risk	(5) Combined
Fiscal conditions model					
Revenue per capita	−0.000041 (0.00)				−0.000082 (0.00014)
Debt ratio	0.29 (0.22)				0.40* (0.24)
Water util. total expend. per capita	0.0069*** (0.001)				0.0055*** (0.00080)
Community characteristics model					
% Black		−0.027 (0.023)			−0.028 (0.027)
% Hispanic		−0.14*** (0.037)			−0.095*** (0.025)
Logged population		−1.97*** (0.37)			−2.08*** (0.41)
Median income		0.023 (0.023)			−0.066 (0.023)
Conservative ideology		−7.74* (4.34)			−5.44** (2.41)
Population density		0.00085*** (0.00)			0.00056*** (0.00017)
Organizational structure model					
Government size			0.090* (0.048)		0.026 (0.072)
Form of government			−1.58** (0.69)		−1.03 (0.76)
Purchased water			4.20** (1.33)		2.86** (0.91)
Environmental risk model					
Health violation				1.27 (0.91)	0.96 (0.86)
Monthly moisture				6.57*** (3.93)	4.11 (1.70)
Surface water				5.96*** (1.08)	5.50*** (0.87)
Constant	34.83*** (1.05)	57.89*** (4.11)	35.40*** (0.78)	32.22*** (1.11)	52.38*** (4.63)
Observations	2119	2119	2119	2119	2119
Adjusted R^2	0.209	0.211	0.213	0.227	0.271
R^2	0.23	0.23	0.23	0.24	0.29
Intercept	38.6	38.6	38.6	38.6	38.6

*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

ranging from $5.00 to more than $163.00 for 6000 gal. This is a wider range than many previous studies have shown, particularly for municipally owned water systems. The variation in these costs is related in part to the financial condition of municipalities, and especially the amount they are spending on their drinking water systems. The outsized importance of debt and spending for water costs points to the investments being made in re-/building infrastructure and the need to recoup those costs through rates.

Environmental conditions are also related to the cost of basic drinking water services. We find that municipalities that rely on purchased water and surface water have higher drinking water service costs. This aligns with our hypotheses informed by prior research, as surface water typically requires more water treatment than groundwater and requires greater effort for regulatory compliance. This is an important finding because surface water is the most common drinking water source for Americans and there are likely to continue to be increasing treatment requirements for surface water-dependent systems. Such requirements have the potential to further raise the cost of water services for surface water-dependent communities. Similarly, utilities that purchase their water may require a more sophisticated organizational structure to procure, maintain, and manage these purchasing contracts. These costs may be warranted, as research shows that utilities that purchase water tend to be in better compliance with SDWA regulations (Allaire, Haowei, and Lall 2018).

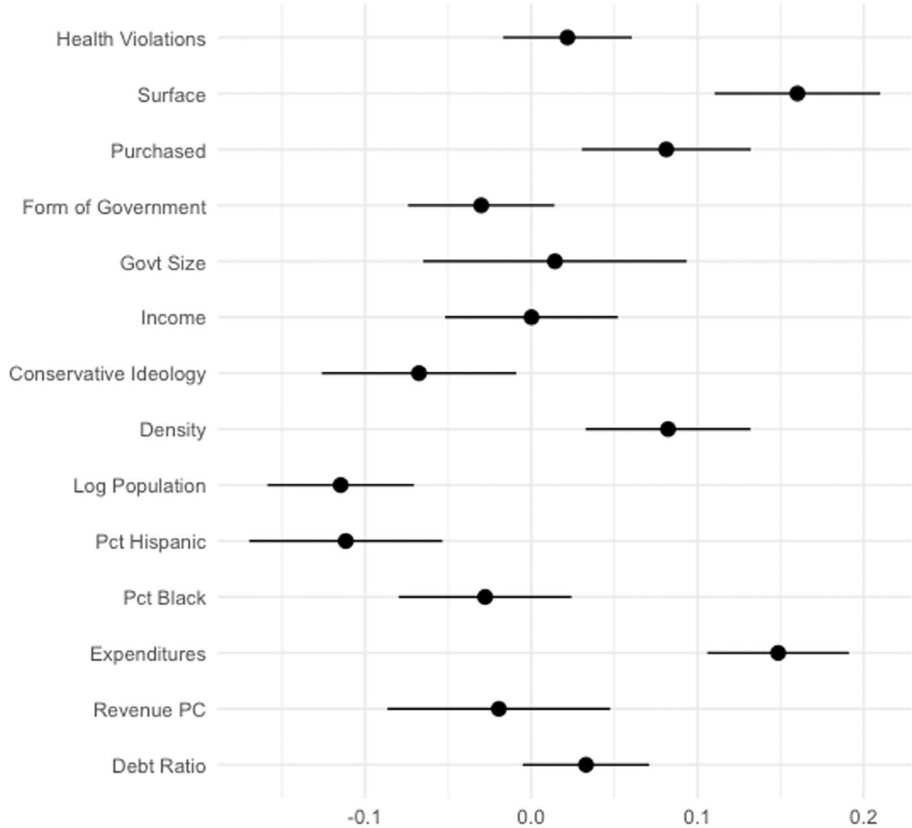

FIGURE 3 | Standardized coefficent estimates and 95% confidence intervals for the combined model (5).

Contrary to our expectations, we find some evidence that drinking water systems in more arid areas tend to charge less for basic drinking water services. We found that on average there is a 16% decrease in cost between the least and most arid cities in our dataset. This finding may reflect the propensity of utilities in arid region to incentive water conservation by charging higher rates for higher water use amounts (e.g., increasing block rates) (Mullin 2008) which may also keep the cost of basic water service low in these regions. Indeed, previous research shows that the relative progressivity of water rates is associated with increasing aridity, which could lead to lower costs for basic services (Switzer 2019).

The socioeconomic and political context of drinking water service provision is also related to the cost to households. We find that larger communities tend to have lower basic water service costs, likely due to economies of scale and capacity associated with operating and maintaining the needed infrastructure. Population size has the largest effect on the cost of basic drinking water services, with a 25% decrease in cost between the smallest and largest cities in our dataset. We also find that municipalities with larger Hispanic populations have lower basic drinking water costs. While these trends are potentially good news for affordability concerns, given the reliance on local revenue for infrastructure investment they may also be indicative of a greater need for investment capacity in these communities.

Finally, we find that politically conservative communities are paying less for drinking water services, with an 18% difference in cost between the most and least liberal cities in our dataset. These findings are some of the first insights into political ideology and the cost of basic water services and support previous work showing the differences in policy priorities in liberal and conservative cities (Einstein and Kogan 2016; Tausanovitch and Warshaw 2013; Gerber 2013; Switzer 2019). We also find that population density has a small but significant positive relationship with the cost of basic drinking water services. This counterintuitive finding warrants further examination in future research.

6 | Conclusion

Our analysis of the cost of basic drinking water services in the United States highlights at least four broad conclusions, which can lead to further examination. First, and as expected, drinking water costs are related to the spending and investment in the water system. Higher levels of spending and investment in the drinking water system, and associated higher water costs, may reflect more consistent maintenance and a more reliable water system. The opposite may also be true, with lower costs signaling a lack of investment and maintenance capacity. While previous studies have found higher water bills in minority communities (Butts and Gasteyer 2011), we find the cost of basic water services to be lower in communities with larger Hispanic populations. While this analysis does not identify the reason for this, given the broader patterns we see in the data, the overall lower cost of drinking water services in Hispanic communities may indicate less infrastructure maintenance and investment, pointing to important policy tensions and the need for creative solutions to ensure drinking water services are both affordable and reliable.

Second, the higher costs already in place for utilities reliant on surface and purchased water may leave them and their users vulnerable to additional investment needs or changes to their water supply driven by climate change or growing demand. The effects of new regulations, such as PFAS standards, or drought conditions that require additional investment or new management strategies, may be felt most acutely by the customers of surface water-dependent systems. These systems may be in most need of additional support to address new regulations and emerging contaminants. Further research could examine these relationships.

Third, the strong negative relationship between population size and the cost of basic drinking water services may lend additional evidence of the pitfalls of extreme decentralization and the growing interest in the regionalization or consolidation of drinking water systems (Bell 2024). National, state, and local level interest in either physical or administrative consolidation of a large number of small drinking water systems has increased over time, mostly due to small systems' poor performance and persistent challenges to investing in needed infrastructure upgrades (Jones et al. 2019). Higher costs for smaller communities indicate there may be additional economies of scale to leverage, but this requires further investigation (Klien and Michaud 2019; Hansen, Mullin, and Riggs 2020).

Finally, our results engage a growing body of research demonstrating the political nature of municipal budgets and infrastructure investments (Peterson 2020; Mullin and Hansen 2022). We find evidence of higher drinking water costs in more liberal and denser communities. This could reflect a relationship between conservative political ideology and preferences for low rates and lower levels of concern for the condition of drinking water infrastructure (Mullin and Hansen 2022). If so, new strategies for raising and accessing adequate revenue may be required in politically conservative communities. However, additional research is needed to better understand the link between political ideology and water costs.

While our findings provide new insight and identify promising areas for additional research into how and why drinking water costs vary in US municipalities, there is also variation our models do not explain and that should be further examined. For example, information about infrastructure age and configuration (e.g., treatment technologies or pumps) is very difficult to find and evaluate systematically and could significantly affect the cost of drinking water provision. Source water quality can also play a role in increasing the cost of treating water to potable standards. Our dataset includes larger (> 10,000 residents) municipalities, and smaller communities could have very different experiences with water costs. Interactions between variables such as density, race/ethnicity, and income could also be further explored, as could potential relationships between SDWA violations and water utility expenditures. Examining the relative contribution of these and other, additional characteristics would be a productive next step.

The results we present here contribute to a growing body of literature examining the cost and affordability of drinking water services in the United States. Our application of an expansive new dataset of municipally owned and operated drinking water systems allows us to deepen our understanding of the underlying drivers of the cost to households of basic drinking water services by taking a national view and incorporating a wider range of environmental and sociopolitical conditions. Additional research and analyses will continue to explore the complex relationships among local conditions and drinking water costs, and the implications of these findings for policy and planning.

Author Contributions

Sara Hughes: conceptualization, data curation, supervision, methodology, writing – original draft, project administration, writing – review and editing. **Christine J. Kirchhoff:** conceptualization, data curation, supervision, funding acquisition, investigation, methodology, writing – original draft, project administration, writing – review and editing. **Michelle Lee:** formal analysis, methodology, writing – original draft, writing – review and editing. **David Switzer:** conceptualization, data curation, methodology, writing – original draft, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix

TABLE A1 | Sensitivity analysis incorporating Democratic vote share from 2020 presidential election.

	(1) Fiscal	(2) Community	(3) Organization	(4) Envt'l Risk	(5) Combined
Fiscal conditions model					
Revenue per capita	−0.0000411 (0.000)				−0.0000235 (0.000)
Debt ratio	0.295 (0.225)				0.454** (0.177)
Water util. total expend. per capita	0.00697*** (0.001)				0.00563*** (0.001)
Community characteristics model					
% Black		−0.119*** (0.044)			−0.103** (0.039)
% Hispanic		−0.143*** (0.051)			−0.0981** (0.038)
Logged population		−1.600*** (0.397)			−1.798*** (0.400)
Median income		0.0123 (0.023)			−0.0152 (0.021)
Conservative ideology		20.00*** (7.003)			14.22** (5.840)
Organizational structure model					
Government size			0.131** (0.049)		0.0176 (0.069)
Form of government			−1.308 (0.822)		−1.138 (0.808)
Purchased water			7.068*** (1.364)		3.709** (1.671)
Environmental risk model					
Health violation				0.509 (0.795)	0.999 (0.891)
Monthly moisture				6.718* (3.612)	4.127 (3.122)
GW				8.012*** (1.108)	5.299*** (1.028)
Constant	34.83*** (1.055)	47.59*** (6.314)	35.40*** (0.781)	32.22*** (1.108)	44.91*** (6.353)
Observations	2119	2003	2119	2119	2003
Adjusted R^2	0.209	0.202	0.213	0.227	0.268
R^2	0.23	0.22	0.23	0.24	0.29

Note: Each column represents the results from a separate OLS regression. The dependent variable reflects the 2017 cost of water in dollars per unit. All models control for state-fixed effects. Robust standard errors, corrected for clustering by state, are in parentheses.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

TABLE A2 | Sensitivity analysis using EPA regions as fixed effects only.

	(1) Fiscal	(2) Community	(3) Organization	(4) Envt'l risk	(5) Combined
Fiscal conditions model					
Revenue per capita	−0.000106 (0.000)				−0.000227* (0.000)
Debt ratio	0.400 (0.260)				0.423** (0.191)
Water util. total expend. per capita	0.00849*** (0.002)				0.00669*** (0.001)
Community characteristics model					
% Black		−0.0297 (0.036)			−0.0398 (0.028)
% Hispanic		−0.0554 (0.062)			−0.00606 (0.043)
Logged population		−1.958*** (0.502)			−2.028*** (0.434)
Median income		0.0403 (0.028)			0.0136 (0.022)
Conservative ideology		−15.17*** (4.261)			−9.592*** (3.482)
Organizational structure model					
Government size			0.136** (0.051)		0.106* (0.056)
Form of government			−1.903* (0.997)		−1.420 (0.853)
Purchased water			7.779*** (1.849)		3.343** (1.419)
Environmental risk model					
Health violation				−0.106 (0.879)	0.700 (0.827)
Monthly moisture				7.063** (3.193)	6.888** (2.793)
GW				8.986*** (1.397)	6.242*** (1.106)
Constant	34.28*** (1.305)	57.41*** (4.979)	35.33*** (1.401)	31.62*** (1.352)	49.48*** (4.845)
Observations	2119	2119	2119	2119	2119
Adjusted R^2	0.128	0.112	0.131	0.155	0.214
R^2	0.13	0.12	0.14	0.16	0.22

Note: Each column represents the results from a separate OLS regression. The dependent variable reflects the 2017 cost of water in dollars per unit. All models control for EPA 10-regions fixed effects. Robust standard errors, corrected for clustering by state, are in parentheses.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.