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Fiscal institutions and racial equity: Determining the price of water

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Abstract

Municipal water utilities across the United States establish their own rate structures to cover operations, maintenance, depreciation, and outstanding debt repayment. Yet, little is known about how rates are determined to ensure equity and/or affordability. To identify sources of variation in residential drinking water rates, we examine municipalities in northeastern Illinois, 2015–2019. Controlling for water utility characteristics, billing structures, financial management, service quality, and demographic/socioeconomic factors, we find no statistically significant correlations between water rates and median household income or race when nonrevenue water from leaking infrastructure is considered, revealing relative racial equity in water pricing within these communities. A larger water distribution network, more water included in the base charge, and a greater number of months in the billing cycle are all associated with lower rates. Purchasing water through an individual or cooperative agreement, a greater proportion of nonrevenue water from leaking infrastructure, a higher minimum monthly base charge, and more revenue debt outstanding (while controlling for nonrevenue water) are all associated with higher rates. We also find a positive correlation between municipal sewer rates and drinking water rates that supports findings from prior research. Overall, our research aids in the development of public policy that ensures all households have access to affordable and safe drinking water to promote water equity and public health.

Key Takeaways

- Our study reveals relative racial equity in municipal drinking water pricing among northeastern Illinois communities, and that rate differentials are more

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attributable to the state of infrastructure in the supply network.
- A cooperative purchasing strategy in the wholesale market is associated with slightly lower rates relative to an individualistic approach to purchasing, which highlights a potential benefit of cooperative purchasing as the ability of members to share capital costs for supply infrastructure.
- The balancing act between affordability and cost recovery in drinking water rate setting will continue to be an important political and policy issue as climate change impacts utilities' access to drinking water sources.
- In addition to understanding the drivers behind water costs, it is also important to examine how this information is communicated to consumers to gain insight into the transparency around the cost of providing clean drinking water.

INTRODUCTION

As of year-end 2023, there were nearly 50,000 community water systems (CWS) across the United States serving more than 300 million people.[1] These independent water systems have a range of characteristics such as size, age, water source type, regulatory environment, and ownership that may impact the overall cost of operating the system and subsequent rates that end users pay. Understanding the drivers of water pricing is vital, as evidence shows that accessibility to affordable, clean drinking water is an important social determinant of individual and community health (Switzer & Teodoro, 2018).

Water affordability and access are also important policy issues that are connected to racial equity. However, whether water pricing variances are due to the age of water infrastructure, its state of repair (or disrepair), the structure of the supply network, or whether demographic and/or socioeconomic characteristics of the customer base are considered to ensure equity and/or affordability, is not widely known. In examining drinking water rates, our research sheds light onto what drives variance in rates among communities and aids in the development of public policy that ensures households of all racial origins and socioeconomic status have access to affordable and safe drinking water.

Municipalities and water utilities also have a high degree of autonomy to determine who they partner with for purchasing water, and how those partnerships are established. This complexity makes it challenging to study water rates and has historically limited past studies to comparisons within regions or individual states (Beecher & Kalmbach, 2013; Hughes et al., 2006; Thorsten et al., 2009) with some exceptions (Zhang et al., 2022). Our study improves upon extant research in that (1) we focus on a single geographical area, (2) where all municipal water providers share one of three common primary sources, (3) the majority of which are inextricably linked through a complex purchasing network, and (4) all share a common regulatory environment.

Our research context is water utilities in northeastern Illinois, which are managed by municipal governments, commissions, single-purpose districts, and private companies.[2]

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[1] Government Performance and Results Act Inventory Report, United States Environmental Protection Agency. https://obipublic.epa.gov/analytics/saw.dll?PortalPages&PortalPath=/shared/SFDW/_portal/Public&Page=Inventory

[2] Northeastern Illinois encompasses Cook County (including the City of Chicago) and its six surrounding counties (DuPage, Kane, Kendall, Lake, McHenry, and Will).

Municipal water utilities operate under Illinois Municipal Code and establish their own rate structures, which are required to be sufficient to cover the costs of operations, maintenance, depreciation, and outstanding debt repayment used to support the provision of drinking water to residents.[3] Yet, there is limited information and empirical study about what factors influence the rates set by these entities. As a contribution to fill this gap in the literature, we use data from a variety of sources to estimate regression models of residential drinking water rates as a function of each municipality's water utility characteristics, billing structures, financial management, service quality, and demographic/socioeconomic factors.

This paper begins with a review of relevant literature on drinking water systems and environmental justice, which we use to inform our analysis. We then describe our model specification, data, and estimation approach. The next section details our regression results. Finally, the implications of the findings are presented along with directions for future research. To summarize our findings in advance, we find no statistically significant correlations between water rates and median household income (MHI) or race when nonrevenue water from leaking infrastructure is considered, revealing relative equity in rates charged to residents of these communities. A larger water distribution network, more water included in the base charge, and a greater number of months in the billing cycle are all associated with lower rates. Purchasing water through an individual or cooperative agreement, a greater proportion of nonrevenue water from leaking infrastructure, a higher minimum monthly base charge, and more revenue debt outstanding (while controlling for nonrevenue water) are all associated with higher rates. We also find a positive correlation between sewer rates and drinking water rates that supports findings from prior research.

RELEVANT LITERATURE

Drinking water systems in the United States are primarily funded through user charges billed to customers of the system (Greer, 2020; Hansen & Mullin, 2022). Establishing the appropriate user charges needed to maintain viability is a core function of governing a water system carried out by municipalities, investor-owned utilities, and single-purpose districts. Decentralized governance promotes greater proximity between policymakers and their constituents that allows for public service delivery and fiscal policy to be tailored to the needs of the community (Oates, 1999). However, the localized implementation of drinking water provision has resulted in a high degree of fragmentation and nearly 50,000 CWS across the United States (Greer, 2020).

This fragmentation results in variation in the physical attributes of a system, socioeconomic characteristics of a utility's customer base, management and operations of a system, and fiscal capacity that must be considered by pricing authorities when establishing user charges in the form of water rates (Bell et al., 2022). Given the reliance of user charges to finance water systems, water rates are treated as a cost recovery mechanism. From a financial sustainability perspective, it is considered a best practice in rate setting to rely on a full-cost water pricing model that efficiently captures the operational, compliance, and fixed costs of the system (Beecher & Shanaghan, 1999). In addition to being a mechanism for recapturing the full cost of operating the system, the rate structure itself serves as a means of distributing the overall cost burden of the system among the customer base of the CWS and can have implications on the affordability of water for some customers.

As a result, there can be an inherent conflict between maintaining affordability and recouping the costs of a system through the rate-setting process (Beecher, 2020). Therefore,

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[3] Private water utilities are regulated by the Illinois Commerce Commission, which approves rate increases. Water districts, commissions, and Joint Action Water Agencies are regulated by different statutes.

variations in water rates across communities can be driven by differences in the characteristics of the system that affect costs of operations, as well as equity considerations of how those costs should be distributed across the customer base. In addition, differences in water rates can reflect who is setting the rate, information they have in setting the rate, what they prioritize, and whether state and/or local laws limit rate changes. As a result of all these factors, even CWS that derive their water from the same source can have vastly different rates.

Cost factors of water systems

Water rates are considered a cost recovery mechanism for water systems (Beecher, 2011; Beecher & Shanaghan, 1999; Pulido-Velazquez et al., 2013; Rogers, 2002; Thorsten et al., 2009). Therefore, the cost of the system should be a prominent determinant of rates. One of the fundamental drivers of end-user rates is the size of a utility, with larger utilities having lower per unit costs and rates (Beecher & Kalmbach, 2013; Hughes et al., 2006; Thorsten et al., 2009). This is due to the relationship between economies of scale and the ability for system costs to be distributed across a larger customer base. While the number of connections is the standard measurement of utility size used by the EPA, research finds that economies of scale are nearly inexhaustible in the treatment of water (Youn Kim & Clark, 1988), meaning the volume of water produced is the driving factor, but not the number of customers that are served by the system. Depending on characteristics of the distribution network such as connection density (Shih et al., 2006; Youn Kim & Clark, 1988), additional service connections can achieve greater economies of scale, but only if the underlying relationships between volume of water provided, size of the distribution area, and density of service connections are not adversely changed (Torres & Morrison Paul, 2006). In general, research has shown that public service delivery in more densely populated urban areas is more cost-effective compared to areas that are characterized by suburban sprawl (Goodman, 2019).

There are also known detriments of undersized and fragmented water systems relative to cost and viability of a system. Smaller systems are less competitive in the labor market for skilled labor, which subsequently reduces technical knowledge and capacity (Teodoro & Switzer, 2016). Smaller systems also have relatively higher numbers of Safe Drinking Water Act (SDWA) violations (Shih et al., 2006). Fragmentation, especially within urban regions, results in disparities of fiscal capacity between communities (Mullin, 2009). These disparities ultimately influence whether a community can make the necessary investments to prevent or respond to SDWA violations (Scott et al., 2018). While system size is important to achieving economies of scale, it does not paint a complete picture.

Economies of scale relate to the functions of production, management, and distribution differently. In terms of drinking water production, multiple studies have found that surface water is more costly to treat and results in higher water rates (Beecher & Kalmbach, 2013; Hughes et al., 2006; Thorsten et al., 2009) due to the higher number of contaminants found in surface water (Wallsten & Kosec, 2008). A recent study comparing drinking water rates in the Chicago metropolitan region found that rates were on average higher for municipalities using Lake Michigan compared to groundwater (Michnick et al., 2022). Groundwater is generally cheaper than surface water to treat for drinking purposes (Beecher & Kalmbach, 2013; Hughes et al., 2006; Thorsten et al., 2009; Wallsten & Kosec, 2008).

While the municipalities in our study area rely on a limited number of water sources for production, the majority are not actively extracting raw water and treating it, but rather rely on wholesale purchasing agreements for treated water. The purchase of treated water through wholesale agreements between utilities is quite common, with nearly a quarter of utilities in the United States relying on purchased water (Beecher & Kalmbach, 2013). However, in extant research, there are competing claims about whether purchasing water is cheaper than treating water. Thorsten et al. (2009) and Hughes et al. (2006) both find that utilities purchasing treated water charge higher rates, possibly due to capital costs being passed along through the sales. Beecher and Kalmbach (2013) find the opposite, arguing that producers are likely forced to internalize these costs, resulting in higher rates. However, these studies do not account for differences in wholesale purchasing strategies. In fact, there is a gap in the literature investigating wholesale drinking water markets in general, which our study helps to fill by considering differences in strategies to purchasing wholesale drinking water.

In fragmented urban regions like northeastern Illinois, providers may seek a more market-based approach than broader regional cooperation since larger collaboratives have coordination and collaboration costs that bilateral agreements do not (Deslatte & Feiock, 2019; Kim et al., 2020). An individual purchasing agreement might also simplify the principal-agent relationship that is more prominent in cooperative purchasing arrangements. However, capital intensity and asset specificity of water systems reduce the risk of defection in collaborations, so larger cooperatives are common in drinking water provision (Deslatte & Feiock, 2019; Kim et al., 2020). Larger arrangements may yield greater economies of scale in purchasing or production through allowing for cofinancing of shared infrastructure, and/or promoting information sharing.

In terms of water utility management, savings through economies of scale can be achieved through administrative consolidation, whereby functionally independent systems are managed through a single administrative agency, though these savings would be limited due to the relative cost of administration compared to infrastructure required for distribution (Shih et al., 2006). Insufficient investment into infrastructure maintenance can result in water loss and the introduction of contaminants (Bell et al., 2022) that increase the cost of a system. As such, infrastructure maintenance that occurs within the useful life of an asset is found to be more cost-effective compared to repairing assets where maintenance has been deferred (Yarnell, 2004).

Infrastructure maintenance plays an important role in distribution; therefore, a utility's strategy for financing infrastructure can influence water rates and their underlying structure. A pay-as-you-go strategy relies on the use of cash reserves to implement a capital improvement plan, while a pay-as-you-use strategy relies on the issuance of debt instruments such as general obligation (GO) or revenue bonds (Greer, 2020). Municipalities may rely on one of these strategies or a combination of both depending on their capital improvement plans and preferences. Hansen and Mullin (2022) note that about 65% of water infrastructure investment in the United States is funded through loans. Municipalities often use debt to finance capital improvements and maintenance of water systems (Greer, 2020; Hansen & Mullin, 2022). Debt outstanding represents a large, fixed cost of the system (Beecher, 2011), as a portion of the rate structure will be used for debt service payments (Greer, 2020; Hansen & Mullin, 2022). Importantly, smaller and poorer communities face higher borrowing costs (Simonsen et al., 2001), which may be a barrier to investment that contributes to further system disrepair and increased operational costs over time or forces a CWS to pass along the higher borrowing costs to users in the form of increased rates. Based upon extant research:

> **H_1:** We hypothesize that cost factors related to production, management, and distribution of a municipal water utility will be correlated with drinking water rates.

Equity considerations

Traditional accounting principles promote achieving revenue neutrality and using pricing as a means of recovering the costs of a system (Griffin, 2001). However, a critique of using an economic approach and focusing on efficient water pricing for cost recovery is that it treats water as a commodity, which has resulted in myriad problems globally (Langford, 2005). Building on the idea of water as a human right, there is a growing body of research in recent years around the concept of water equity, which uses an environmental justice lens and acknowledges that there are racial and income disparities in drinking water access, quality, and affordability (Osman & Faust, 2021).

Within this body of growing literature, there are two streams that are relevant to analyzing variation and determinants of rates. The first is related to disparities in fiscal capacity, or the ability for a CWS to generate sufficient financial resources from its economic base necessary to maintain its system (Mullin, 2009). In general, communities serving higher portions of low-income households will have greater difficulty generating sufficient revenue without creating economic hardship (Patterson & Doyle, 2021). These disparities are driven by political fragmentation that can arguably be tied to historical land use policies and annexation decisions that excluded poorer Black neighborhoods (DeHoog et al., 1991; MacDonald Gibson et al., 2014), coupled with "White flight" and disinvestment in urban centers with concentrated poverty (Sadler & Highsmith, 2016). Mullin (2020) notes that increased political fragmentation is often correlated with higher degrees of economic and racial segregation. In their comparison of residential water costs across the state of Michigan, Butts and Gasteyer (2011) found that zip codes with higher non-White populations pay higher annual amounts for water. However, their study does not consider other system characteristics that might explain such variance in residential water bills. In general, disparities in fiscal capacity tied to demographic trends, legacy costs, and economic changes could contribute to variation in rates across communities, based on the ability to invest in infrastructure and control different cost drivers of the systems.

The second stream of literature that is relevant to our analysis is related to water affordability and the internal equity considerations that public officials take to reduce economic burden. Maintaining affordable rates for consumers and access to safe drinking water are complex issues. The EPA sets an "affordability threshold" for water bills (drinking water alone) at 2.5% of national-level MHI, which varies according to the socioeconomic characteristics of the population served. However, this metric of affordability has come under scrutiny due to its inability to account for the economic burden of a community's lower-income households (Teodoro, 2018).

Maintaining affordability within communities that have a higher prevalence of low-income households can be exceptionally challenging. Bell et al. (2022) finds that there is a tension between maintaining affordability and generating sufficient revenues to sustain a water system's reliability in communities with a lower economic base. This indicates that rate-setting authorities in communities with more vulnerable populations may suppress rates to maintain affordability for their customers, though this may result in increasing costs over time due to infrastructure degradation. For example, communities that have higher proportions of low-income and Black or Hispanic populations are found to have relatively higher numbers of SDWA violations (Switzer & Teodoro, 2018).

Taken together with the previously discussed research, this points to complexity in understanding how equity issues may influence water rates. On the one hand, we might expect rates to be higher in low-income and non-White communities because of fiscal capacity. On the other hand, elected officials in those communities may be mindful of their constituents' abilities to pay for water and set rates below full cost to address affordability concerns. Based upon extant research:

> **H_2:** We hypothesize that equity considerations in the form of demographic and socioeconomic characteristics of a municipal utility's customer base will be correlated with drinking water rates.

DATA AND MODEL SPECIFICATION

The mixed findings within the literature concerning water cost factors and equity considerations, as well as nuances in water pricing processes, highlight the difficulties in explaining variation in the amounts end-users pay for drinking water. However, extant research provides important context to guide our investigation of disparities in rate setting across communities. In northeastern Illinois, Lake Michigan is a dominant resource of drinking water. Despite Illinois comprising less than 4% of Lake Michigan's coastline, more than 60% of the people who rely on it as a primary source of drinking water are Illinois residents.[4] The Illinois Department of Natural Resources (IDNR) is the authorizing agency for issuing permits to divert Lake Michigan water for domestic use and annually monitors the volume of water supplied to ensure the state of Illinois is in legal compliance with various federal rulings.[5] Entities seeking a diversion permit must follow a lengthy review process and demonstrate that an alternative source, such as groundwater, is insufficient to meet the needs of the population served. If approved, the permit specifies the maximum volume of water that can be consumed by that entity. However, IDNR does not regulate how municipal utilities are managed or how water is sold between permittees.

Several sources provide data for our study. The Prairie Research Institute at the University of Illinois is responsible for conducting the statewide Illinois State Water Survey (ISWS), which involves collecting, analyzing, archiving, and disseminating data and technical information to be used by policymakers and the public.[6] In part, these data describe the complex water acquisition and distribution network of the more than 1300 communities throughout Illinois, including the different sources of water (e.g., Lake Michigan, other surface water from rivers and reservoirs, and/or groundwater) and the types of purchasing agreements (i.e., purchased water) entered into by municipalities who do not self-produce (i.e., withdraw and treat) their drinking water. We combine the ISWS data with billing and rate data (reported biennially) from the Northeastern Illinois Water and Sewer Utility Rate survey for all municipalities in the northeastern Illinois region for fiscal years 2015, 2017, and 2019).[7]

We collected water use data summarized at the municipal level from the Illinois Department of Natural Resources (IDNR). As previously discussed, drinking and sanitary water use of Lake Michigan water is managed by IDNR through a permitting system. All permittees are required to submit an annual audit report, which includes volume of Lake Michigan water allocated (via IDNR permit), volume of water supplied, volume of water billed, and “nonrevenue water.” Nonrevenue water is defined as water that was delivered but not billed, water lost in the system through leaks, and water fraudulently obtained through meter tampering or illegal reconnections. The IDNR data are limited, however, to only municipalities that use Lake Michigan water.

We also included data from the EPA's Safe Drinking Water Information System (SDWIS), which reports information on past and current violations, number of connections, and ownership type. Finally, we combined data collected from these sources with municipal-level financial and demographic/socioeconomic data obtained from the State of Illinois Comptroller and US Census Bureau to specify and estimate Equation (1) for municipality *i* in year *t*.

$$WR_{it} = \alpha + WC_{it}\beta_1 + BS_{it}\beta_2 + FM_{it}\beta_3 + SQ_{it}\beta_4 + DS_{it}\beta_5 + \varepsilon_{it}. \tag{1}$$

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[4] For additional information, please visit the Illinois Environmental Protection Agency website: https://www2.illinois.gov/epa/topics/water-quality/monitoring/Pages/lake-michigan.aspx#:~:text=However%2C%20despite%20its%20small%20size,10%20million%20lake%2Dwide

[5] A 1967 US Supreme Court decree (amended in 1980) dictates the rules for diverting water from Lake Michigan. The ruling stipulates that the state of Illinois is legally allowed to divert an average of 3200 cubic feet of water per second, based on a 40-year running average, for all uses, including water for drinking and sanitary purposes, maintaining navigable waterways, and stormwater runoff that is unnaturally diverted from Lake Michigan's natural watershed (Wisconsin v. Illinois, 388 US 426 [1967]; Modified 449 US 48 [1980]).

[6] For additional information on the Illinois State Water Survey (ISWS), please visit their website at https://www.isws.illinois.edu/about

[7] These data are made available by the Chicago Metropolitan Agency for Planning (CMAP) and the Illinois–Indiana Sea Grant (IISG) Program (collectively referred to as CMAP–IISG). Our analysis is restricted to the northeastern region of the state because there is no public data source available that reports water rate data for the remainder of the state of Illinois. Also, while the 2021 fiscal year rate data recently became available, data from some of the other sources used for analysis are not yet reported for 2021, so the 2019 fiscal year is the most recent year of available data.

Although we are unable to expand the number of municipalities or years analyzed due to limits on data availability, our data reflect the largest possible sample size for the northeastern region of the state and for the most recent time period possible. Descriptions of all variables and data sources are provided in Table 1. Below we discuss specific variables and related sub-hypotheses.

Dependent variable

In Equation (1), our dependent variable WR_{it} represents the standardized residential water rate per 5000 gallons consumption per month on a ¾″ service line. Due to significant variation in how municipalities calculate their water rates, direct comparisons are impossible at face value. Therefore, to account for differing fee structures and block pricing arrangements, we standardize municipal water rates using a common consumption volume (5000 gallons[8]), billing frequency (monthly), and service line size (3/4″), as shown in Appendix A.

Cost factors of water systems

Water utility characteristics

The vector WC_{it} contains a series of variables measuring characteristics of the municipal water utility, including the number of service connections, service connection density, water source, purchasing agreement, and nonrevenue water. As noted earlier, utility size has been shown to lower per unit costs and rates (Beecher & Kalmbach, 2013; Hughes et al., 2006; Thorsten et al., 2009) as economies of scale exist in water treatment and distribution. Number of connections is the standard measurement of utility size used by EPA. However, additional connections do not necessarily yield economies of scale, but rather may be dependent on other characteristics of the distribution network such as connection density (Shih et al., 2006; Youn Kim & Clark, 1988). As such, we hypothesize that municipalities with greater numbers of service connections and connection densities will be associated with lower rates, as they benefit from economies of scale and lower risk of water loss compared to smaller and less densely connected networks.

In terms of water source, groundwater is cheaper than surface water to treat for drinking purposes (Wallsten & Kosec, 2008). Since our data include both source types, we use a dichotomous variable to control for water derived from surface sources, which we hypothesize will be associated with higher rates.

As discussed earlier, there are competing claims about whether purchasing water is cheaper than treating water (Beecher & Kalmbach, 2013; Thorsten et al., 2009). Our sample includes both municipalities that self-produce their own water and those that purchase water from wholesalers through either an individual or cooperative agreement. We hypothesize that municipalities providing purchased water will be associated with higher rates than municipalities with withdrawn water (i.e., self-producers, the excluded category to avoid perfect collinearity). We further hypothesize municipalities with individual purchasing agreements will exhibit higher rates than municipalities in cooperative purchasing agreements due to the latter having more powerful negotiating power as a collective and the ability to share capital costs for supply infrastructure.

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[8] CMAP-IISG and the University of North Carolina's Environmental Finance Center have previously used the 5000 gallons per month as a standardized measure to compare rates across the region and populate the water and sewer rate dashboard. We used the raw survey data published by CMAP-IISG to calculate rates at 5000 gallons per month for each year 2015, 2017, and 2019.

TABLE 1 Variables and data sources.

Variable	Description and data source
Dependent variable	
Standardized water rate	Calculated water rate in dollars per 5000 gallons of water.[1]
Water utility characteristics	
Service connections	Total number of service connections in distribution network.[2,3]
Connection density	Total service connections per 100 square miles.[2,3]
Surface water source	Dichotomous variable coded 1 if municipality obtains water only from surface water sources; and 0 otherwise.[3]
Individual purchasing agreement	Dichotomous variable coded 1 if municipality purchases wholesale water using an individual purchasing agreement with another entity; and 0 otherwise.[3]
Cooperative purchasing agreement	Dichotomous variable coded 1 if municipality participates in a cooperative purchasing agreement with a Joint Action Water Agency (JAWA), Commission, or Water District; and 0 otherwise.[3]
Nonrevenue water ratio	Total amount of nonrevenue water reported as a percentage of total water supplied.[4]
Billing structures	
Monthly base charge	Total dollar amount of minimum monthly base charge.[1]
Water in base charge	Total amount of water included in monthly base charge.[1]
Months in billing period	Number of months in billing period: Monthly = 1, Bi-Monthly = 2, Quarterly = 3.[3]
Standardized sewer rate	Calculated sewer rate in dollars per 5000 gallons of sewage.[3]
Financial management	
Property tax share	Percentage of municipality's total revenue generated from property taxation.[5]
G.O. water debt outstanding	Per capita amount of general obligation water debt outstanding in dollars.[5]
Revenue water debt outstanding	Per capita amount of revenue water debt outstanding in dollars.[5]
Expenditure per connection	Total dollar amount of water utility fund expenditures per service connection.[2,3,5]
Service quality	
Health-based violations	Dichotomous variable coded 1 if municipality received at least one health-based violation of the Safe Drinking Water Act (SDWA); and 0 otherwise.[3]
Demographic and socioeconomic factors	
Vacancy rate	Percentage of property within the municipality that is vacant.[6]
Median age	Median age in years of residents living within the municipality.[6]
Median household income	Median household income of residents living within the municipality in thousands of dollars.[6]
Black/Hispanic population	Percentage of resident population living within the municipality that are Black or Hispanic.[6]

(Continues)

TABLE 1 (Continued)

Variable	Description and data source
Manufacturing jobs	Percentage of manufacturing jobs in municipality.[6]
Occupied household size	Average household size of occupied housing units in municipality.[6]

[1] *Source*: Chicago Metropolitan Agency for Planning (CMAP), Northeastern Illinois Water and Sewer Utility Rate Data.

[2] *Source*: Environmental Protection Agency (EPA) Safe Drinking Water Information System (SDWIS) Federal Reporting Services.

[3] *Source*: University of Illinois, Illinois State Water Survey.

[4] *Source*: Illinois Department of Natural Resources.

[5] *Source*: State of Illinois, Comptroller Financial Database.

[6] *Source*: US Census Bureau.

Finally, evidence suggests there is often a premium paid for undelivered and/or unbilled water (Baird, 2010) because disrepair increases the costs of infrastructure maintenance over time. To consider this, we include the ratio of nonrevenue water to total water supplied in a subsample analysis, because these data are not reported by all municipalities and are only available for 2 of our 3 fiscal years. We hypothesize that municipalities with higher proportions of nonrevenue water will be associated with higher rates, as nonrevenue water includes amounts of water supplied but not billed, nonsaleable water system loss, and consumer malfeasance, all of which decrease the supply of billable water and may require subsidization from paying consumers in the form of higher rates.

Billing structures

Although water rates generally reflect the amount of water consumed by users, charges can be structured in different ways to ensure that sufficient revenue is generated to cover operations, maintenance, and debt service payments (Carroll et al., 2023). Depending on how the base charge is calculated and implemented, it will result in a different distribution of system cost burden across the customer base and affect affordability for different customers (Pierce et al., 2020). The vector BS_{it} contains variables measuring billing structures that might influence water rates, including the monthly minimum base charge, the amount of water included in the base charge, water billing frequency, and the municipality's sewer rate.

Water utilities may structure rates to include a fixed amount or monthly minimum base charge that all customers pay regardless of consumption (American Water Works Association, 2000). This rate structure is used to guarantee a minimum amount of revenue collection to meet fixed costs related to the system; therefore, we hypothesize a higher monthly minimum base charge will be associated with higher rates charged to residents. However, there is variation in the amount of water consumption that is included in a monthly minimum base charge. So, we also include a variable measuring the amount of water in this minimum base charge and hypothesize that a higher amount of water (in gallons) included in a municipality's base charge will be associated with lower rates, as the base charge covers a greater amount of water consumption before unit rates are applied to individual consumers.

We also include a variable measuring the number of months in a municipality's billing cycle to control for variation in monthly, bi-monthly, and quarterly billing. Less frequent billing can reduce administrative costs for water utilities, although it can make household budgeting more difficult. Controlling for billing cycles accounts for part of the administrative burden of the system. We hypothesize that a greater number of months in the billing cycle, indicating less frequent billing, will be associated with lower rates charged to residents.

Finally, municipalities may elect to combine the billing and/or accounting of their water and sewer systems into a single enterprise fund. For example, Hughes et al. (2006) found that municipalities that provide both water and sewer services have higher rates when wastewater is being discharged into a protected watershed. As such, we include a control variable measuring a municipality's sewer rate per 5000 gallons of sewage (in a subanalysis since sewer rates are not available for all municipalities), which we standardize in the exact same way as drinking water rates (see Appendix A), to offer some initial indication of whether municipal provision of both services is more costly for residents. We hypothesize that municipalities with higher sewer rates will also be associated with higher drinking water rates.

Financial management

The vector FM_{it} contains variables controlling for financial management of the municipality and its water utility, including the proportion of a municipality's total revenue generated from property taxation, per capita amounts of GO and revenue water debt outstanding, and total water utility fund expenditures per service connection. The percentage of total municipal revenue derived from property taxation serves as an indicator of the general level of service provision preferred by residents (Tiebout, 1956) and/or fiscal capacity, as this general revenue source might be used to subsidize capital spending or water systems operating at a financial loss (Greer, 2020). We hypothesize that property tax revenue will be positively or negatively correlated with water rates.

As previously discussed, municipalities often use debt to finance capital improvements and maintenance of water systems (Greer, 2020; Hansen & Mullin, 2022). Debt outstanding represents a large, fixed cost of the system, as a portion of the rate structure will be used for debt service payments (Greer, 2020; Hansen & Mullin, 2022). As such, we hypothesize that the per capita amounts of GO and revenue water debt outstanding will be associated with higher water rates.

Finally, since water rates are considered a cost recovery mechanism for water systems (Beecher & Shanaghan, 1999; Beecher, 2011; Pulido-Velazquez et al., 2013; Rogers, 2002; Thorsten et al., 2009), the cost of the system should be a prominent determinant of rates. We hypothesize that a higher dollar amount of water utility fund expenditures per service connection, as an indicator of overall system cost, will be associated with higher rates.

Service quality

The vector SQ_{it} contains a variable measuring the presence of health-based violations of the SDWA as an indicator of drinking water service quality. Health-based violations may trigger capital spending, depending on their cause, which could increase system costs and rates (Allaire et al., 2018; Scott et al., 2018). As such, we hypothesize that health-based violations will be associated with higher rates, as system operators must expend resources to remedy any violations received.

Equity considerations

Demographic & socioeconomic characteristics

As previously discussed, equity considerations are important as indicators of fiscal capacity or the ability for a CWS to generate sufficient financial resources from its economic base necessary to maintain its system (Mullin, 2009), as well as those potential actions public officials might take to reduce economic burden for their constituents. The vector DS_{it} contains variables controlling for demographic and socioeconomic characteristics of a municipality's resident population, including the property vacancy rate, median age, MHI, percentage of Black and Hispanic population, proportion of manufacturing jobs, and average size of occupied housing units. Vacancy rate controls for connections that are counted in system size but not producing any revenue for system. This may be exacerbated in rust belt cities that long ago built infrastructure for heavy use by large populations but now must cover fixed costs with a smaller customer base. We hypothesize that the vacancy rate will be associated with higher water rates since property owners are not contributing financially to cover water system costs even though the properties are serviced by the system.

The median age of a community might influence water consumption habits and/or household size. We hypothesize that municipalities with higher median ages of residents will be associated with higher rates as these communities might contain greater numbers of retirees who do not work outside their home and therefore consume more water during daytime hours but may be on age-related payment assistance programs that subsidize their consumption.

MHI directly relates to water affordability and equity, as wealthier individuals likely demand more and/or better water. As such, we hypothesize that wealthier communities will be associated with higher rates. Similarly, extant research on water affordability and equity has highlighted the connection between race and water rates (Gregory et al., 2017; Osman & Faust, 2021). In line with prior findings, we hypothesize that a higher percentage of Black and Hispanic resident population within a municipality will be associated with higher water rates.[9]

Large water users such as manufacturers also shape the distribution of system cost burden (Beecher, 2011). Equity-based rate setting would require large water users who contribute more towards overall system costs to pay a higher proportion, subsequently reducing residential rates. However, elected officials may also structure rates to be competitive when recruiting industry. As such, we include the proportion of manufacturing jobs within the municipality; however, we cannot predict the coefficient sign for this variable, as some communities might charge higher rates to households to subsidize industrial water consumption to remain competitive from an economic development standpoint, whereas other municipalities might not charge for residential consumption but rather depend fully on industrial usage to cover water system costs.

Finally, including a variable measuring the average size of occupied households provides a way to control for population served as well as the number of users per connection. We hypothesize that municipalities with larger occupied household sizes will be associated with lower rates as larger households likely demand higher levels of water consumption, which has been associated with benefits realized from economies of scale (Hughes et al., 2006).

DESCRIPTIVE STATISTICS

Descriptive statistics for all variables are provided in Table 2. As can be seen, municipalities in our sample exhibit standardized rates of $39.42 per 5000 gallons of drinking water, on average, which ranges from a low of $6.15 (in Richmond in both 2017 and 2019) to a high of $97.61 inflation-adjusted dollars (in Elmwood Park in 2017).[10] This compares to an average standardized sewer rate of $20.96 per 5000 gallons, ranging from $0.29 in Park Forest in 2015 to $96.32 in Bannockburn in 2019, in inflation-adjusted dollars. According to the mean values in Tables 2, 37.5% of municipalities have entered into individual purchasing agreements, while nearly 27% are part of cooperative purchasing

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[9] We recognize that race and median household income may not be significantly correlated with water rates alone (Teodoro & Switzer, 2016). As such, we also interacted these two variables in a subanalysis as added consideration of these potentially important drivers related to affordability and equity in drinking water provision. In this subanalysis, the interaction term between median household income and Black/Hispanic population was statistically significant at the 99% confidence level ($t = 4.24$); however, the magnitude of the coefficient (0.000004) was effectively zero even when centering the variables. As such, we excluded this subanalysis from our final results but will provide the results upon request.

[10] All dollar values were adjusted for inflation using the Consumer Price Index and reflect 2019 constant dollars.

agreements, compared to 35.5% (the excluded category to avoid perfect collinearity, not shown) who self-produce their drinking water.

Figure 1 illustrates two examples of individual versus cooperative purchasing agreements commonly found among Illinois municipalities. The lefthand panel in Figure 1 shows an individual purchasing agreement in which there is a single supplier and a single purchaser. In this example,

TABLE 2 Descriptive statistics.

Variable	Mean	Standard deviation	Minimum	Maximum
Dependent variable				
Standardized water rate	$39.42	$14.61	$6.15	$97.61
Water utility characteristics				
Service connections	9388.16	35,005.94	160	514,143
Connection density	1051.28	674.89	30	4298
Surface water source	0.6678	0.4714	0	1
Individual purchasing agreement	0.3750	0.4845	0	1
Cooperative purchasing agreement	0.2697	0.4442	0	1
Nonrevenue water ratio*	14.84%	8.98%	0.32%	53.24%
Billing structures				
Monthly base charge	$14.01	$11.80	$0.00	$85.83
Water in base charge	1332.58	1587.74	0	10,000
Months in billing period	1.87	0.78	1	3
Standardized sewer rate	$20.96	$15.70	$0.29	$96.32
Financial management				
Property tax share	21.23%	10.18%	0.59%	68.72%
G.O. water debt outstanding	$116.40	$339.58	$0.00	$2940.19
Revenue water debt outstanding	$36.07	$238.03	$0.00	$3786.44
Expenditure per connection	$801.93	$599.21	$39.58	$5446.29
Service quality				
Health based violations	0.65	2.49	0	29
Demographic & Socioeconomic Factors				
Vacancy rate	6.75%	3.79%	0%	23.29%
Median age	39.57	5.36	22.80	56.70
Median household income	$84,324.96	$34,338.36	$23,995.26	$250,001.00
Black/Hispanic population	29.69%	25.94%	0.70%	96.26%
Manufacturing jobs	6.06%	4.11%	0%	28.88%
Occupied household size	2.77	0.29	1.94	3.86
$N = 608$ ($i = 197$ in 2015; $i = 209$ in 2017; $i = 202$ in 2019)				

*Data only available for years 2015 and 2017 and only for those municipalities reporting; $N = 284$ ($i = 135$ in 2015; $i = 149$ in 2017).

Highland Park has three individual purchasing agreements: one with Bannockburn, one with Deerfield, and one with Lincolnshire. The righthand panel in Figure 1 illustrates a cooperative arrangement, whereby multiple municipalities come together to form a new joint entity such as a water commission or Joint Action Water Agency (JAWA). These joint entities either engage in a single purchasing agreement on behalf of their members with a supplier, or jointly produce water through a shared treatment facility, and then water is resold to their members at a specified wholesale rate. In Figure 1, the Northwest Suburban Municipal JAWA purchases water from Chicago and redistributes to its seven municipal members.

Figure 2 illustrates the potential connection among water rates and these three different acquisition arrangements. As can be seen, municipalities who self-produce their drinking water

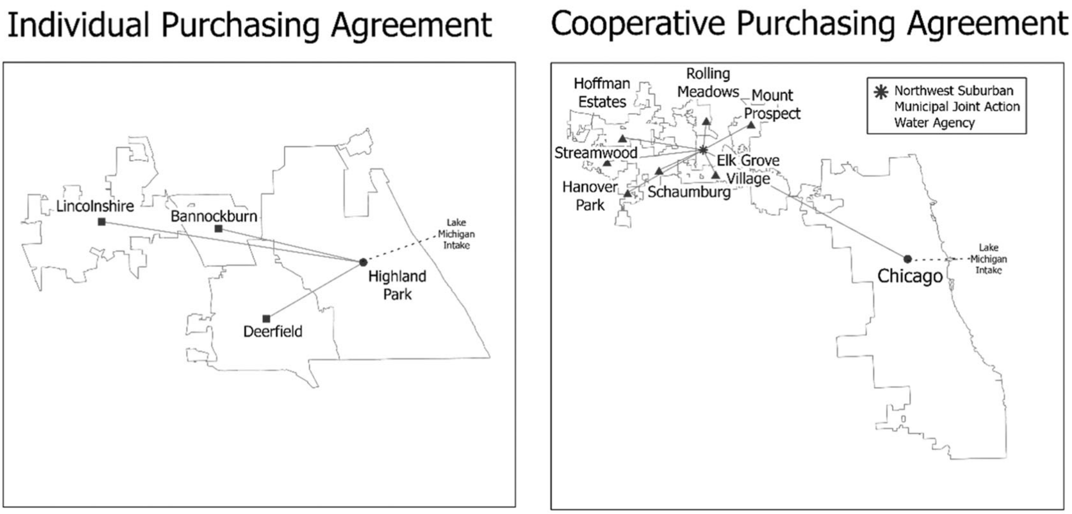

FIGURE 1 Examples of water purchasing arrangements.

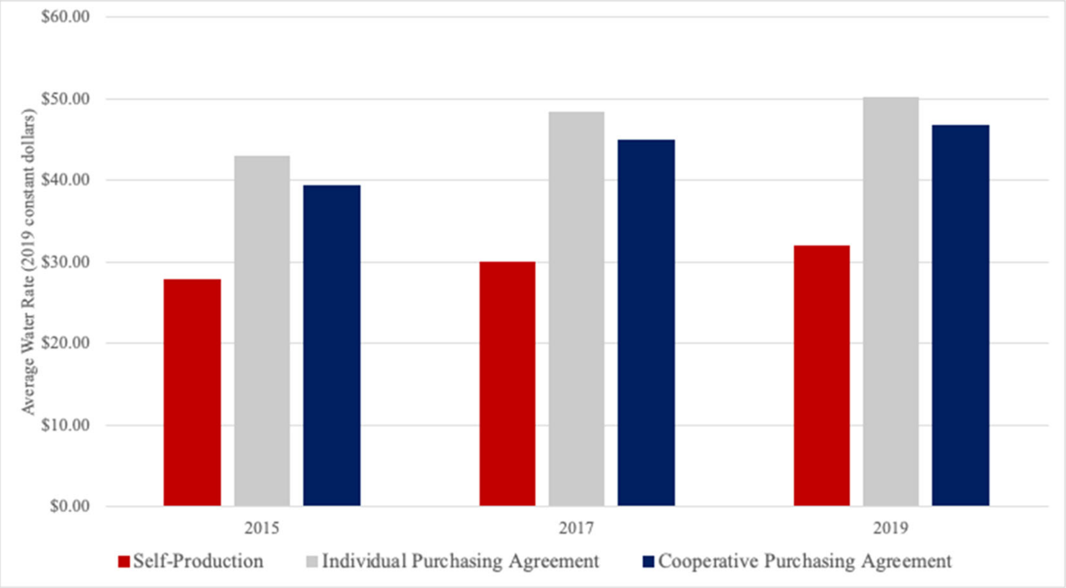

FIGURE 2 Average standardized water rates per 5000 gallons, by acquisition type and year.

exhibit noticeably lower average standardized rates per 5000 gallons water (in 2019 constant dollars), which range from $27.80 in 2015 to $31.84 in 2019. For municipalities relying on purchasing agreements, the differences in average standardized water rates appears rather small between municipalities entering into individual purchasing agreements versus those in cooperative agreements. Specifically, the average standardized rates per 5000 gallons water (in 2019 constant dollars) for individual purchasing agreements range from $42.83 in 2017 to $50.06 in 2019. This compares to that of cooperative purchasing agreements at $39.33 in 2015 to $46.60 in 2019.

Other descriptive statistics of note in Table 2 indicate that municipal water systems in Illinois maintain 9388 total service connections and 1051 connections per 100 square miles on average, 66.78% of municipalities derive their water from surface sources, and jurisdictions lose an average of 14.84% of their supplied water from the saleable system (i.e., nonrevenue water). Municipalities maintain a minimum monthly base charge of $14.01 on average, which includes an average consumption amount of 1332.58 gallons. With a mean value of 1.87, most municipalities have monthly or bi-monthly billing cycles. Property taxes account for 21.23% of total municipal revenue on average. On a per capita basis, northeastern Illinois municipalities have $116.40 in GO water debt and $36.07 in revenue water debt outstanding, on average, and expend an average of $801.93 per service connection. Finally, it is worth noting that these Illinois municipalities maintain, on average, a 6.75% property vacancy rate, 39.57 median age, $84,324.96 MHI, Black and Hispanic resident populations of 29.69%, 6.06% of manufacturing jobs, and an occupied housing size of 2.77 individuals.

REGRESSION RESULTS

Table 3 provides three sets of regression results. As noted earlier, it is common for municipal utilities to combine their water and sewer billing in practice; however, not all municipalities operate their own sewer systems even if they maintain their own drinking water systems. Thus, the inclusion of any variable(s) measuring characteristics of municipal sewer systems inherently reduces our sample size by excluding those municipalities without sewer systems. In addition, nonrevenue water is only reported by municipalities with Lake Michigan as a primary water source and is only available for two (2015 and 2017) of our three fiscal years.

We begin our empirical analysis by excluding these variables from Model 1 and use it as a base model for comparison. We then add the variable measuring a municipality's sewer rate into Model 2, and then further add the nonrevenue water variable into Model 3. All models are estimated using Ordinary Least Squares (OLS) regression with year-fixed effects and robust standard errors.[11] All models are statistically significant overall at the 99% confidence level and explain between 61.46% and 74.16% of the overall variation in standardized residential water rates.

Water utility characteristics

Table 3 shows that both purchasing agreement variables reach statistical significance at the 99% confidence level in all models, indicating a municipality's method of water acquisition is an

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[11] We elected not to use municipality fixed effects for the following reasons: (1) due to limits on data availability, we do not observe each municipality each year, leading to an unbalanced panel, which might bias coefficients produced by fixed effects regression for panel data estimation; (2) we are most interested in explaining the variation in water rates across municipalities in northeastern Illinois rather than the variation within each municipality over time; and (3) using fixed effects regression to estimate Model 3 is not feasible with only 2 years of data available, and using a different estimation approach for Model 3 (i.e., OLS) would not be strictly comparable to the results for Models 1 and 2 if fixed effects regression were used for estimation.

TABLE 3 OLS determinants of standardized water rates.

Variable	**Model 1: Base model** **Coefficient**	***t***	**Model 2: Sewer rate added** **Coefficient**	***t***	**Model 3: Nonrevenue water added** **Coefficient**	***t***
Water utility characteristics						
Service connections	−0.00003	−4.13***	−0.00004	−3.66***	−0.00006	−4.04***
Connection density	0.00186	2.17**	0.00256	2.73***	0.00135	1.58
Surface water source	1.40345	0.81	1.85944	1.00	2.25933	0.86
Individual purchasing agreement	9.26312	5.88***	8.62103	5.33***	11.02783	5.67***
Cooperative purchasing agreement	10.54311	6.79***	9.66960	6.05***	10.95184	5.75***
Nonrevenue water ratio	--	--	--	--	0.14235	2.67***
Billing structures						
Monthly base charge	0.85309	14.35***	0.88734	12.56***	1.16954	15.76***
Water in base charge	−0.00404	−7.54***	−0.00421	−6.73***	−0.00686	−12.12***
Months in billing period	−2.33061	−4.47***	−2.45692	−4.47***	−2.45289	−3.82***
Standardized sewer rate	--	--	0.07327	2.28**	0.12753	2.41**
Financial management						
Property tax share	0.10472	2.79***	0.11866	2.85***	0.15006	2.33**
G.O. Water debt outstanding	0.00216	1.75*	0.00136	1.17	−0.00058	−0.41
Revenue water debt outstanding	−0.00229	−2.43**	−0.00250	−2.39**	0.01315	3.04***
Expenditure per connection	0.00054	0.70	0.00157	1.59	0.00184	1.76*
Service quality						
Health-based violations	0.03170	0.26	0.08177	0.71	0.05186	0.18
Demographic & socioeconomic factors						
Vacancy rate	0.07892	0.74	0.04078	0.35	−0.04872	−0.24
Median age	0.09131	0.72	0.11717	0.90	−0.05823	−0.31
Median household income	0.00002	0.79	0.00001	0.55	0.00003	1.02
Black/Hispanic population	0.07519	2.44**	0.08521	2.56**	0.03206	0.88
Manufacturing jobs	−0.44975	−3.66***	−0.45076	−3.45***	−0.21550	−1.32

TABLE 3 (Continued)

Variable	Model 1: Base model		Model 2: Sewer rate added		Model 3: Nonrevenue water added	
	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*
Occupied household size	2.57134	1.01	0.78573	0.26	−2.54634	−0.88
Constant	10.62653	1.12	12.14279	1.12	23.37572	1.99**
N	608		554		254	
F	48.70***		43.09***		23.12***	
R^2	0.6146		0.6287		0.7416	
Mean VIF	2.09		2.13		2.43	

Note: Although not shown, all models include year-fixed effects.

Abbreviation: OLS, Ordinary Least Squares.

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

important indicator of its rates charged to consumers. In addition, these variables have the largest magnitudes of coefficients among all variables in our analysis. According to Table 3, municipalities that acquire water through an individual purchasing agreement are associated with rates that are between $8.62 (Model 2) and $11.03 (Model 3) per 5000 gallons higher on average than municipalities who self-produce (the excluded category) their drinking water. Notably, the coefficients for this variable in Models 1 and 2 are lower than in Model 3 when nonrevenue water is introduced, illustrating the need to subsidize nonsaleable water loss from the system through higher rates. Table 3 also shows that municipalities engaged in cooperative purchasing agreements exhibit rates per 5000 gallons water that are $9.67 (Model 2) to $10.95 (Model 3) higher on average compared to those municipalities who self-produce. These results conform to our hypothesis that municipalities providing purchased water to residents are associated with higher rates than municipalities with withdrawn water (i.e., self-producers). Contrary to expectations, we find cooperative purchasing agreements are associated with slightly more expensive rates—by $1.05 (Model 2) to $1.28 (Model 1) higher, on average—than individual purchasing agreements. However, when nonrevenue water is introduced in Model 3, these variables conform to expectations with cooperative purchasing agreements exhibiting rates that are $0.08 lower on average than rates associated with individual purchasing agreements. This finding emphasizes the importance of being part of a collective to share capital costs for supply infrastructure.

As expected, we find that larger utilities are associated with lower rates. Table 3 shows that each additional service connection is associated with water rates that are $0.00003 (Model 1) to $0.00006 (Model 3) lower on average, which is very small due to scaling of the variable. If we think about this in standard deviation terms, an increase of one standard deviation in the number of service connections, which amounts to 35,006 new connections, would exhibit lower standardized water rates between $1.05 and $1.97 on average. Although service connection density is statistically significant and positive in Models 1 and 2 at the 95% confidence level or above, its statistical significance disappears in Model 3 when nonrevenue water is introduced. In addition, water source fails to reach statistical significance in all models. As such, it appears that the EPA's measure of overall water utility size (i.e., number of service connections) is a better predictor of rates for municipalities in northeastern Illinois.

Finally, Model 3 in Table 3 shows that nonrevenue water influences rates charged by municipalities as expected. Among municipalities that use Lake Michigan as their primary water source, Table 3 shows that a one percentage point increase in the proportion of nonrevenue water to water supplied is associated with $0.14 higher rates per 5000 gallons on average. This finding reflects the average amount by which municipalities must increase rates to compensate for supplied but unbilled water, water loss from the system, and fraudulently obtained water.

Billing structures

Our findings related to billing structures shown in Table 3 all conform to expectations in terms of the directions of coefficient signs (positive or negative). As can be seen, a one dollar increase in the minimum monthly base charge is associated with an increase in rates of $0.85 (Model 1) to $1.17 (Model 3) per 5000 gallons on average. Conversely, each additional gallon of water consumption included in the minimum base charge exhibits lower water rates, on average, by $0.004 (Model 1) to $0.0069 (Model 3) per 5000 gallons. Alternatively, a one standard deviation increase in the amount of water included in the minimum base charge (1587.74 gallons) is associated with rates that are between $6.41 (Model 1) and $10.89 (Model 3) per 5000 gallons lower on average. In addition, each additional month in a billing cycle, which reduces billing frequency and associated administrative costs, is associated with reductions in water rates of $2.33 (Model 1) to $2.46 (Model 2) per 5000 gallons on average. Finally, Table 3 shows that a one dollar increase in a municipality's standardized sewer rate is associated with drinking water rates that are $0.07 (Model 2) and $0.13 (Model 3) per 5000 gallons higher on average. This finding supports extant research that municipalities providing both water and sewer services are associated with higher rates (Hughes et al., 2006).

Financial management

Table 3 illustrates some surprising and inconsistent results pertaining to the influence of utility financial management on water rates. First, GO water debt outstanding fails to reach statistical significance in all models except for at the 90% confidence level in Model 1. In addition, total expenditures per connection (our proxy for overall system cost) fails to reach statistical significance in all models except for at the 90% confidence level in Model 3 when nonrevenue water is introduced, potentially suggesting system leakage is associated with higher costs passed onto consumers, but more research is needed to consider this slight correlation definitive.

To the contrary, Table 3 consistently shows a positive correlation between property tax share and drinking water rates that is statistically significant in all models at the 95% confidence level or above. Specifically, a one percentage point increase in a municipality's total revenue generated from property taxes is associated with water rates that are between $0.11 (Model 1) and $0.15 (Model 3) per 5000 gallons higher on average. These findings suggest property taxation in northeastern Illinois is perhaps used to subsidize capital spending or water systems operating at a financial loss (Greer, 2020) rather than reflecting the general level of service provision preferred by residents (Tiebout, 1956). We draw this conclusion based upon the greater coefficient magnitude in Model 3 when nonrevenue water is introduced, which serves as a proxy for system disrepair and perhaps the broader condition of infrastructure in the community.

Finally, Table 3 shows that the per capita amount of revenue water debt outstanding is associated with lower water rates in Models 1 and 2 and with higher rates in Model 3 when nonrevenue water is introduced. Specifically, a one standard deviation increase (used for interpretation due to variable scaling) in the per capita amount of revenue water debt outstanding ($238.03) is associated with water rates that are $0.54 (Model 1) to $0.59 (Model 2) per 5000 gallons lower on average. However, when nonrevenue water is introduced and the analysis is restricted to municipalities sourcing their water from Lake Michigan, the same amount of increase in revenue water debt outstanding is associated with rates that are $3.13 (Model 3) per 5000 gallons higher on average.

Service quality

As can be seen in Table 3, the health-based violations variable used to measure service quality fails to reach statistical significance in all models.

Demographic & socioeconomic factors

Although extant research provides little guidance regarding which demographic and socioeconomic factors might influence drinking water rates or how they might do so, perhaps what is most surprising from Table 3 is how little influence we find among these variables. Vacancy rate, median age, and occupied household size all fail to reach statistical significance in all models. The proportion of manufacturing jobs is statistically significant at the 99% confidence level and negative in Models 1 and 2, exhibiting average rates of $0.45 per 5000 gallons lower on average, suggesting industrial water consumption may be used to subsidize residential water use. However, this variable fails to reach statistical significance in Model 3 when nonrevenue water is introduced.

Table 3 also shows that MHI fails to reach statistical significance in all models, suggesting the general wealth of residents within a municipality has no bearing on water rates charged. As such, we focus our interpretation on the race variable. Models 1 and 2 in Table 3 show (at a 95% confidence level) that a one percentage point increase in the proportion of Black and Hispanic residents is associated with higher rates of $0.08 (Model 1) to $0.09 (Model 2) per 5000 gallons on average. However, this variable fails to reach statistical significance in Model 3 when nonrevenue water is introduced. This finding suggests that among municipalities sourcing water from Lake Michigan, Black and Hispanic residents face no different rates for drinking water, but rather likely reside in communities with more deficient infrastructure and that is a more prominent determinant of any rate differentials observed.

CONCLUSION

Our study fills a gap in existing research by analyzing water pricing across a geographically confined urban region where most municipal water systems share a common pool resource and water source. In the economically and racially segregated context of northeastern Illinois, our research reveals that variance in water rates is somewhat related to socioeconomic factors, but only before the quality of communities' infrastructure is considered. Using OLS regression with year-fixed effects for estimation, we found no statistically significant correlations between water rates and MHI in any of our models. We did find that municipalities with higher proportions of Black and Hispanic residents were associated with higher rates for drinking water before nonrevenue water (i.e., water supplied but not billed, water leakage from the system, and water obtained through malfeasance) was considered; however, that correlation disappears when this indicator of infrastructure quality is included in the model estimation. As such, our study reveals relative racial equity in water pricing within these communities, and that rate differentials are more attributable to the state of infrastructure in the supply network.

Still, our findings reveal a degree of complexity and nuance in understanding what drives differences in water pricing across communities, especially within a region where hundreds of municipal water providers are tapping into the same few sources for drinking water, and most are functionally reliant on other communities through wholesale purchasing agreements. Consistent across the three models and existing research (Hughes et al., 2006), is the finding that purchasing treated water has the largest correlation with residential rates. While both purchasing variables have positive coefficients across the models, a cooperative purchasing strategy in the wholesale market is associated with slightly lower rates relative to an individualistic approach to purchasing, but only when nonrevenue water is considered, which highlights a potential benefit of cooperative purchasing as the ability of members to share capital costs for supply infrastructure. Although our operationalization of the purchasing agreements are simple dichotomous variables, our research provides some of the first insight into a municipal wholesale water market. A higher minimum monthly base charge and more revenue debt outstanding (while controlling for nonrevenue water) were also associated with higher rates, while a larger water distribution network, more water included in the base charge, and a greater number of months in the billing cycle were all associated with lower rates. We also find a positive correlation between municipal sewer rates and drinking water rates that supports findings from prior research.

There are a few limitations of this research worth noting. First, empirical studies such as ours are only as good as the data available for analysis. In this regard, it should be noted that no universal or nationwide source of data for drinking water rates exists. In fact, even the water rate data used in this analysis are not available statewide or for any areas within Illinois outside of the northeastern geographical area. We recognize this potential limit to the generalizability of our results to other regions beyond northeastern Illinois and perhaps even the rest of the state where Lake Michigan is not such a prominent source of drinking water. Still, we utilized the population of municipal water rate data that is available. And we do consider northeastern Illinois to be comparable to other regions with a dominant shared source of water and/or where the provision of drinking water is fragmented. Lack of data is an important impediment to understanding the relationship between the cost of delivering safe drinking water and racial equity and water affordability in rate setting. As such, a fruitful area for future research is additional studies examining determinants of water pricing in other jurisdictions.

Second, it is quite likely that the state of repair or disrepair of a municipality's infrastructure is an important factor influencing water rates; however, we lack the ability to directly observe or measure the condition of each municipality's infrastructure. Our best attempt was through the nonrevenue water variable. However, one challenge is that nonrevenue water data are not systematically collected for municipalities in Illinois that are not permitted to withdraw drinking water from Lake Michigan. Another challenge is that this variable includes three components: water leakage from the system, unbilled water, and water consumed illegally. It is likely that the ratios of these three components vary across municipalities, but there is no way to separate each component to more directly capture system leakage, the best indicator of infrastructure disrepair. And, including the measure of nonrevenue water in our analysis reduced our sample size by roughly 60%, thereby potentially further limiting the generalizability of our results.

Another important consideration is the fact that the rate-setting process is inherently a political process. While "best-practices" around rate setting emphasize efficient and sustainable cost recovery, the decisions around water pricing are subject to the influences of any policy decision. Inadequate information, competition, and institutional influences can result in water rates that do not truly reflect the real cost of providing drinking water. Our analysis is not able to consider these other factors.

Finally, although we believe the use of OLS regression with year fixed effects was the best and most appropriate estimation method (see Footnote 11), our empirical results might suffer from omitted variable bias that is potentially avoided by using two-way fixed effects for estimation. However, we believe the fact that our sample consists solely of municipal governments, all operating within a single state, and all operating in close geographic proximity, suggests that any potential bias from unobserved factors influencing any particular municipality is minimized. As a precaution, however, we avoid referencing any sort of causal relationship in our analysis.

By revealing the drivers of variance in water rates, this research aids in the development of public policy that ensures all households have access to affordable and safe drinking water. Access to clean and affordable drinking water is tied to the broader issues of racial equity and environmental justice, as the water crises in Flint, Michigan, and Jackson, Mississippi, as well as the water shutoffs in Baltimore, Maryland, and Detroit, Michigan, have shown. Water utilities and public officials are tasked with providing residents clean drinking water while also maintaining the necessary infrastructure. Since water rates are the key revenue source for water utilities, this creates a challenge in that water pricing needs to be sufficient for the operational costs and maintenance of the system while also taking into consideration water affordability at the household level. This balancing act between affordability and cost recovery in rate setting will continue to be an important political and policy issue as climate change impacts utilities' access to drinking water sources.

While our study sheds light on the drivers behind variance in water rates among northeastern Illinois municipalities, more research is needed to understand the factors that influence costs of drinking water provision, and the linkages between issues of water affordability, accessibility, and infrastructure. Local utilities and decision makers establish water rates and fees; however, as our research shows, water pricing varies between municipalities even when the source of water is the same. Future research could examine the policy process for water pricing to better understand the factors that local utilities and decision makers take into consideration when setting water rates, fees, and taxes. As existing research has demonstrated that the fiscal capacity of water systems is vital for maintaining infrastructure (Scott et al., 2018), examining how a local governments' larger fiscal condition may impact water rates is an especially fruitful direction as it would shed light on how broader municipal fiscal stress materializes into local taxes and fees, and ultimately impacts households. In addition to understanding the drivers behind water costs, it is also important to examine how this information is communicated to consumers to gain insight into the transparency around the cost of providing clean drinking water.

Finally, our analysis also includes variables related to an individual municipality's approach to the wholesale market, which is the first water rate study to our knowledge to consider purchasing strategies. Given the large coefficients for both purchasing variables, and the subtle differences between them, more research is needed to understand the nuances in wholesale purchasing and the inner workings of intergovernmental organizations created for collective purchasing and co-financing infrastructure. Along a similar line, studies related to linked purchasing and regional supply chains would also be fruitful. There is a growing literature utilizing network analysis in the study of supply chains in the private sector, but less is known about how supply chain structures influence public service costs.

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APPENDIX A

Standardized monthly water rates (WR_{it}) per 5000 gallons consumption are calculated as shown in Equations (A1) and (A2).

$$WR_{it} = FC_{it} + VC_{it}, \tag{A1}$$

$$VC_{it} = \frac{(5,000 - WB_{it})}{BU_{it}} \times WC_{it}. \tag{A2}$$

In Equation (A1), FC_{it} represents a municipality's monthly fixed (i.e., base) charge, which is calculated by dividing bimonthly base charges by 2, quarterly base charges by 3, and so forth. VC_{it} reflects the monthly volumetric charge for water consumption. For municipalities with a *flat* *rate structure*, a fixed amount is charged for water (i.e., $FC_{it} > 0$) regardless of actual consumption, so $VC_{it} = 0$ in Equation (A1). Conversely, for municipalities with a *volumetric rate structure*, $FC_{it} = 0$ in Equation (A1) as the amount charged for water is based entirely on actual consumption (i.e., $VC_{it} > 0$).

For municipalities utilizing a water rate structure with both fixed and volumetric components, VC_{it} is calculated for 5000 gallons water consumption as shown in Equation (A2). In Equation (A2), WB_{it} represents monthly gallons (converted from other volumetric units, such as cubic feet, as necessary) of water consumption included in the base charge (i.e., FC_{it} in Equation A1). BU_{it} represents the number of water billing gallons (converted from other volumetric units, such as cubic feet, as necessary) in the base charge. So, the fraction in Equation (A2) calculates the monthly gallons of water consumption that are billed on a volumetric basis after the base charge is applied, where positive values reflect water consumption that exceeds the amount included in the base charge. For municipalities that include 5000 or more gallons of water consumption in the base charge, the fraction in Equation (A2) is zero or negative, and $VC_{it} = 0$; in such cases, $WR_{it} = FC_{it}$. Otherwise, WC_{it} reflects the volumetric charge, which may be applied uniformly, as an increasing block rate, or as a decreasing block rate. It should be noted, however, that our calculations of standardized water rates at 5000 gallons water consumption only exceeded the first water block for one municipality.