America's Water: An exploratory analysis of Municipal Water Survey Data

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Executive Summary

This paper presents a comprehensive analysis of the driving factors behind variability in water rates across the nation. It offers a brief analysis of historical trends in water utility rates and debt in the United States, followed by analysis of the 2010 American Water Works Association (AWWA) survey and publicly available data, such as the U.S. Census demographic data and climate data from the National Atmospheric and Oceanic Administration (NOAA). The variability of water rates nationwide is examined in the context of two key rate-setting variables: operating expenses and debt. Four factors – water source, utility size, population, and climate – are proposed as underlying factors that influence trends in rates through their impact on debt, operating expenses, or both. Utilities are additionally evaluated on metrics defined in this paper that evaluate labor efficiency and the extent of cost recovery through rates.

The analyses in this paper are primarily exploratory in nature and include regressions, correlations, boxplots, and maps where geographical distribution may be of interest. Key figures are included in the text, and additional supporting figures are provided in the Appendix for the sake of brevity. Section III goes beyond exploratory analysis and proposes a multivariate grouping model that considers all the rate-variable relationships explored in Section II simultaneously and separates utilities into similar clusters based on the most significant rate-to-variable relationship(s).

The key findings of this paper are as follows:

- **Utility debt and water rates increased from 2000-2010, by 33% and 23% respectively.** The overall increase is disproportionately driven by the top-third of utilities, which have debt and rate increases over 100%.
- **Operating expenses and rates are well-correlated, but with significant variability.** Utilities far above the trend may have exceptionally large debt commitments, or fewer sources of revenue outside collected residential charges. Those far below the trend are highly reliant on sources other than rates (i.e. property taxes or connection fees) to cover operating expenses.
- **Source matters, and relative to other sources, groundwater is the least costly.** The median groundwater rate for 1500 cubic feet is $30 compared to $37, $44, and $42 for surface, split and purchase/other respectively. Resale utilities balance operating expenses 40% higher than other sources with lower debt ratios.
- **Source diversity is expensive and driven by supply scarcity.** Split source utilities have several differentiating factors; they have higher rates, fixed revenues, cost recovery, and higher productivity than other sources. In addition, they tend to be very large utilities located in areas with the lowest annual precipitation, suggesting that water scarcity can

push utilities to diversify their sources, resulting in higher costs to the utility and higher rates for the customer.

- **Small utilities have the highest operating expenses.** The middle fifty percentile of operating expenses for small utilities ranges from $1900 to $3400 per Million Gallons (MG) compared to $1600 to $2600 per MG for medium utilities, and $1800 to $2500 per MG for large utilities, highlighting the economies of scale with size.
- **Small and medium utilities are those with the highest and lowest debt utilities.** The median debt ratio for large utilities is 0.42 compared with 0.30 and 0.28 for medium and small utilities, respectively. However, the bottom 50% of small and medium utilities have little to no debt, while many small and medium utilities carry higher debt than any of the larger utilities, indicating that the average trend is not characteristic of the entire range of utilities.
- **Large utilities are the most likely to recover full costs through rates, despite having more debt commitments and the lowest fixed charges.** All large utilities have a high cost recovery, indicating that they have little dependence on revenue from sources other than rates. No large utilities have zero debt, compared with 8% of medium utilities and 18% of small utilities. Interestingly, large utilities derive a larger fraction of their revenue from variable consumption-related charges as opposed to fixed charges.

This paper highlights the rise of expensive split source utilities in water scarce areas and the abundance of low rate and low debt small utilities, many of which have aging infrastructure and no clear mode of financing for upgrades in the near future. One drawback of the AWWA survey used in this study was the absence of annual debt service; quantifying the annual principal and interest payment owed by a utility is key to assessing the ability of rates to recover costs in the short term. As such, future surveys should include debt service. Additional detailed analysis of individual utilities costs, with particular focus on energy, labor, and other operations and maintenance costs, would help affirm some of the preliminary conclusions and interpretations proposed here.

Introduction

At the time of its last national water use survey in 2005, the United States Geological Survey (USGS) reported that 86% of the US population obtained its domestic water from a public supply source, up from 70% in 1955. This reflects continuing urbanization as well as public investment in drinking water infrastructure. From 2000 to 2010, the Census Bureau reported, the South and West grew almost 15% in population, compared to less than 4% in the Midwest and Northeast. The arid states of Nevada, Arizona, and Utah all experienced over 20% population growth. At the same time, water infrastructure in the US has deteriorated to a critical level. In its 2009 Report Card for American Infrastructure, the American Society of Civil Engineers (ASCE) gave the drinking water infrastructure a D- grade. It cited an $11 billion annual deficit for replacing aged-out facilities and updating to meet new regulations (before accounting for growing demand), 7 billion gallons of drinking water lost daily from leaking pipes, and an average of 850 pipe main breaks daily across the country. This situation arises in part due to decreasing federal government contributions towards investments in public water infrastructure since the 1980s.

The combination of the population shift towards water scarce areas and aging infrastructure nationwide puts increasing financial and operational stress on water utilities. This burden appears to increasingly be on the consumer. Reports of a changing status quo in sources of capital funding abound. Circle of Blue reported that the Conference of Mayors found that 99% of all expenditure on drinking water in 2005 ($45.6 billion) came from local governments. Most recently the Water Environment Federation (WEF) reported that the Drinking Water State Revolving Fund's budget was cut almost 10% from 2012 to 2013, to $829 million, a miniscule number relative to the $11 billion annual deficit (WEF, 2012). The American Water Works Association (AWWA) recently published a national analysis of utility piping systems and projected replacement and needs. It estimates that $1 trillion are needed over the next 25 years. Of this, 54% is for replacement and the remainder to account for demand growth and population migration (AWWA, 2011). With growing demand concentrated in the West and South, water supplies are stressed and utilities are increasingly turning to new, and often more expensive sources, such as desalination, recycled water, and aquifer storage and recovery. Other regions face declining or stabilizing populations and may have to shift lost revenue from new connection fees to actual water consumption charges.

Though lack of investment is a well-quantified problem, overinvestment in infrastructure plagues some utilities as well. The traditional model of long-term development is to project future demand due to population growth, and expand the capacity of the existing infrastructure to meet these demands in an anticipatory manner, with the goal of maintaining high reliability and high quality supply. The recent experience in some locations (such as Tampa Bay, Florida) has been that in the absence of federal funding of local water infrastructure, water rates increase to cover the utility's debt service to pay for the new infrastructure. In many cases the rate increase creates a response in demand, as consumers take conservation actions such that the total consumption from the system and also the total net revenue are reduced below the levels anticipated. This decrease in demand leads to an over-designed infrastructure in the short run and a revenue shortfall in the long-run that makes it difficult for the utility to cover the debt service load, thus decreasing the financial resilience of the utility and the community. Understanding the extent that such situations are present in the US, and developing a new model of conservation, renovation and development of water infrastructure, is a challenge.

Many studies have evaluated rate structures and pricing mechanisms through case analysis. The goal of our current work was to pursue a national-scale, econometric analysis of the association between drinking water utility costs, water sources, operational factors, geographies and demand relative to the nominal rates charged by the utility. We explore how these associations vary across the U.S.A, and attempt to find dominant utility groups associated with a certain combination of rate and cost characteristics. We observe that even though some utilities have similar operating costs, they differ widely in the rates charged. Distinguishing rate variability resulting from costs and demand factors, such as supply costs or economies of scale, from variability which may be more performance related, such as cost recovery or efficiency, highlights the variety of challenges, largely in terms of investment needs and supply constraints, that utilities may face in coming years.

Existing analyses of water rates fall into three broad tiers. The first tier includes national surveys, often only of large American cities, that primarily report rising rates, and may also include a few broad utility characteristics. Circle of Blue, an online news source for water scarcity issues has surveyed the water and sewer rates of 30 major American cities since 2010 (Walton et. al, 2012. Black & Veatch, a global engineering, consulting and construction company, has conducted the *50 Largest Cities Water and Wastewater Survey* six times since 2001. The biennial AWWA Water & Wastewater Survey, conducted since the 1990's is the primary dataset used in this analysis. The second tier includes in-depth regional analyses, published by research centers with academic or industry partners that focus on analyses of policies, financial planning and ultimately utility-level recommendations for rate setting, demand projection and other decision-making processes. Examples include *Water Pricing Primer for the Great Lakes Region (Beecher et.al, Alliance for Water Efficiency)* and the *Need to Know Water Rates Series* for California (Pacific Institute). The third tier covers a large set of local and regional analyses of rate setting practices, price elasticity, demand forecasting, and revenue stability. This in-depth analysis of local data of rates, financial parameters, and consumer consumption behavior, that typically centers on a single utility or service area, can be very useful, but is not attempted here given the wider scope of the analysis.

The *Primer on Water Pricing* (Beecher et. al, 2011) states: "Moving toward economic and environmental sustainability argues for improving water cost knowledge for water systems of all types, regardless of size, ownership, management, or resource conditions. Pressure on costs and prices brings greater urgency and importance to incorporating costs into the rates charged for water services." In this spirit, we present one of the first analyses to systematically explore the national level survey data on water rates and driving factors to provide a macro level description and understanding of the major reported factors that influence operational costs, rates and financial balances of water utilities. First, trends from limited historical survey data are presented as a premise for the main statistical analysis of extensive current survey data. The main analysis aims to relate water rates to their driving costs based on utility traits, climate and demographic variables. The intent is to provide normative benchmarks for utility performance relative to the group of utilities that have similar scale, hydroclimate, physical, demographic and socio-economic attributes.

I. Historical Trends: AWWA Water & Wastewater Surveys 2000-2010

In collaboration with Raftelis consultants, AWWA publishes a biennial survey, the *AWWA Water & Wastewater Rate Survey* (see Appendix A for detailed definitions of all survey variables). Historical data was extracted from six AWWA surveys conducted between 2000 and 2010. Only the utilities responding a minimum of three times over the ten-year period (50% of surveys) were included. This corresponds to 197 utilities for historical rate analysis, 131 utilities for historical debt analysis, and 126 utilities with complete records for both debt and rates. The AWWA survey data provide additional support to other sources (such as Circle of Blue and Reuters) showing rising rates and debt, and confirm them across a broader sample of utilities and a longer time period (five surveys in ten years). Additionally, it is shown that especially large increases in the top third of rates and debt are significantly correlated and disproportionately responsible for the overall average increase.

Rates. Reports and analysis of rapidly increasing water rates especially for the major cities in the USA are widespread. In June 2012, Circle of Blue reported an 18% average increase in rates in 30 major U.S. cities, with 7% in the past year. In September 2012, USA Today published an analysis of over 100 municipalities and concluded that over one-fourth increased rates over 100% in the past twelve years (McCoy, 2012). Based on the sample from the AWWA Water and Wastewater Rate Surveys, the average monthly cost of 1500 cubic feet (cf) of water rose from $22.80 in 2000 to $38.30 in 2010, a 68% increase, or 32.5% after accounting for the general inflation rate[1]. A map of water rate changes across the country is provided in **Figure 1**. Interestingly, high and low rate increases are often geographically clustered. The lowest reported rate remained around $10, while the highest rates rose from $54 in 2000 to above $90 per 1500 cf in 2010. The rate increase trend can be further decomposed into statistically significant differences based on utility size. The 2010 AWWA Water & Wastewater survey classifies

[1] The rate of increase was computed from a minimum of three data points for 1500 cf of monthly use across the 2000, 2002, 2004, 2008, 2008 and 2010 surveys, since not all utilities responded in each year. Since the reported increases for many utilities are over periods of less than ten years, the percent increase may be an underestimate. Inflation was accounted for using the CPI inflation calculator from the Bureau of Labor Statistics.

utilities in three size categories; **small** utilities producing less than twenty million gallons per day (MGD), **medium** utilities producing between twenty MGD and seventy-five MGD and **large** utilities producing more than seventy-five MGD. There is a significant difference in the median historical rate change of large and small utilities; the median rates increase was 62% and 31% for large and small utilities respectively. Medium utilities fall between large or small utilities, but the difference is not statistically significant[2] (see Appendix C for supporting figure).

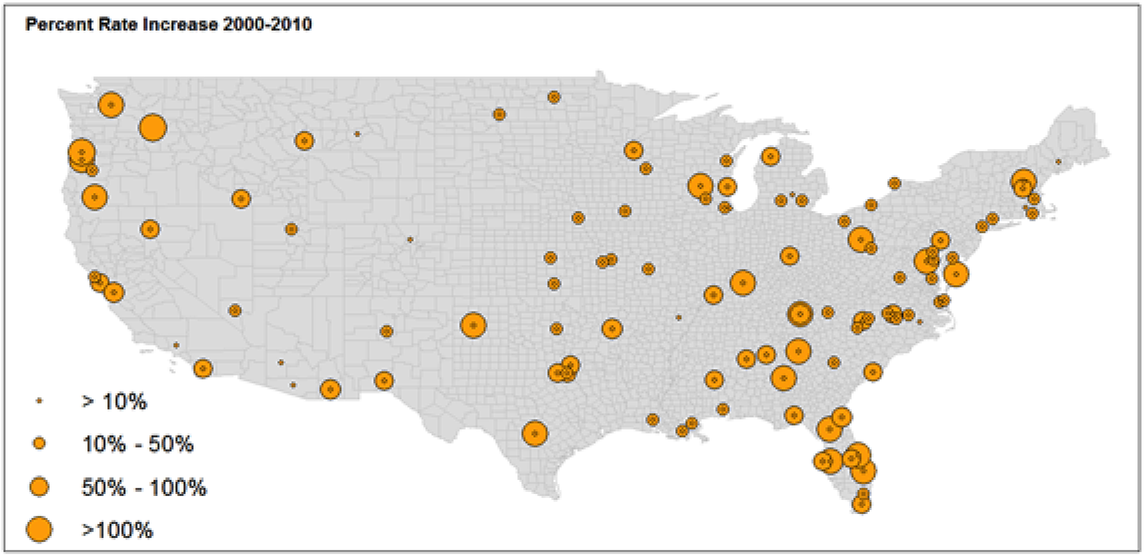
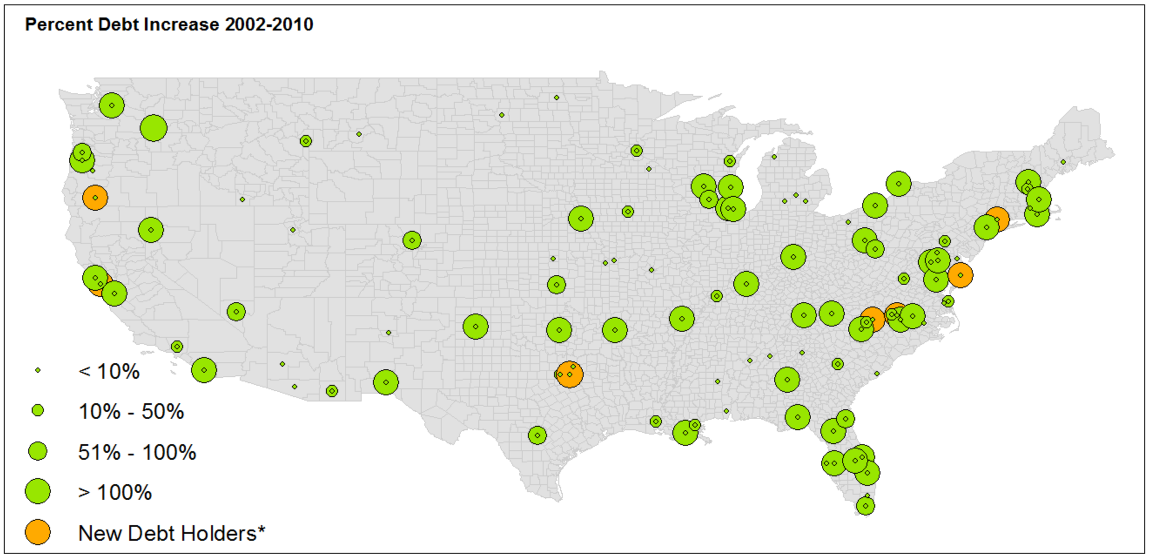


Figure 1: Water Rate Increases from 2000 - 2010

Debt. From 2002-2010 the median increase of long-term debt (normalized by million gallons of water sold) was 23%, including an adjustment for inflation[3]. Approximately a third of these utilities reported debt increases of over 100% and more than half of the top third reported increases of over 200%. **Figure 2** maps the debt increases across the country; there are clusters of high increases in certain geographic regions including Florida, Chicago, and coastal cities in both the East and West. In April 2012, Reuters reported that water utilities have $330 billion in outstanding debt, representing about 10% of the municipal bond market. The first quarter of 2012 alone saw $11 billion in new water utility bonds issued (Barghini, 2012). Whether through municipal bonds, or a pay-as-you-go approach, which uses higher rates to pay for infrastructure on an annual basis, most utilities must operate as at-cost utilities meaning users ultimately shoulder the cost of new infrastructure. Some still receive funding through property taxes and other fees, or receive loans from state or federal revolving funds, but ultimately the cost is in some way shouldered by the community. Rate increases and debt increase have a weak positive correlation (Pearson's r = 0.26). The correlation is higher if only the large debt increases

[2] Statistically significant with $p \leq 0.05$

[3] Similar to the rates, debt change was computed from a minimum of three years of reported long-term debt values, but within the 2002-2010 time period (no reported debt values in the 2000 survey).



*New Debt Holders are defined as those who reported ~zero debt in their earliest survey response, followed by significant debt values reported in later surveys (> 500% increase).

Figure 2: Long Term Debt Increase from 2002 - 2010

(above 100%) are considered, as shown in the boxplot in **Figure 3**. A boxplot represents the spread of a set of values; the heavy horizontal line in the middle of the box indicates the median value, the top and bottom of the box indicate the 75th and 25th percentile, respectively. The whiskers stretch one-and-a-half times the interquartile range (IQR) – which is the distance between the 25th and 75th percentile – above (below) the 75th (25th) percentile lines. Values lying outside the IQR are designated by dots, and can be considered outliers. The 52 utilities with debt increases in excess of 100% have a median rate increase of 73% compared to 38% median increase in rates for utilities with debt increase less than 100%. The IQR of rate increases is 44% to 110% for utilities with debt increases above 100%, and 20% to 55% for utilities with less than 100% debt increase, indicating very little overlap between the groups. Unlike rate changes, the percent change in debt was not significantly different for utilities of different sizes.

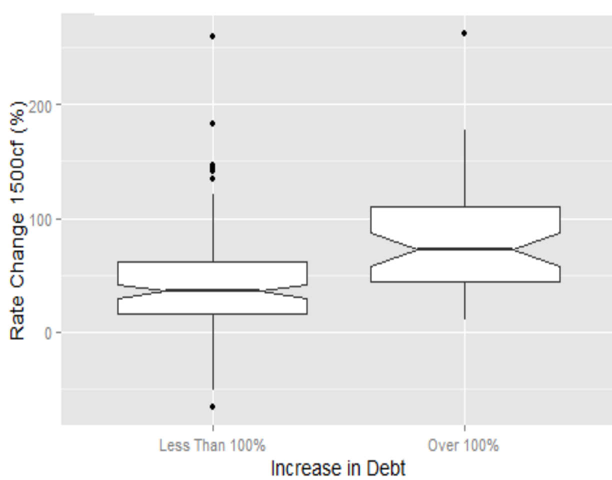


Figure 3: Rate Increases are lower for utilities with debt increases less than 100% (on the left) from 2002-2010 and higher for utilities with debt increases than 100% (on the right).

Exploring the differences in the increases in rates and debt across utilities emerges as an interesting task. Because not all the historical surveys include operating expenses, water source, or demographic information, we focus on an in-depth analysis of the recent 2010 results to suggest possible drivers for some of the results observed in the historical analysis presented above.

II. 2010 Water Rate Survey: Exploratory Data Analysis

The Data

Over 1000 utilities were polled in the 2010 AWWA Water and Wastewater Survey. Primarily public utilities[4], totaling 341 utilities that together serve approximately 38% of the American population, responded. The utilities represent 49 states and Washington, DC. Water supply data is provided by 308 utilities, with the remaining being wastewater providers only. Of these, 194 are combined utilities that also provide wastewater data and the remaining are drinking water only utilities (eight of which are entirely wholesale). An additional 33 utilities are wastewater only utilities. The combined financials of water and wastewater utilities reflect costs beyond producing and supplying water, namely treating wastewater and managing storm water. The operating expenses of combined utilities, when normalized by drinking water production, were consistently higher than those for drinking water only utilities, suggesting a possible bias in results if combined financials are analyzed without any distinction from separate (water or wastewater only) financials. Some combined utilities provided separate financial data for their drinking water entities, while others did not. To simplify the analysis, and focus solely on the cost and rates of water supply utilities, only the 212 primarily retail utilities reporting water only rates and water only financials were considered[5]. Of these 212 utilities some did not report key financial variables such as debt and assets. These utilities were consequently excluded from the analysis of any financial variables and the grouping analysis (Section III) resulting in a ***reduced sample of 194 utilities.*** In addition to the survey, county-level population and climate data is obtained in the U.S. census and National Oceanic and Atmospheric Association (NOAA), respectively.

Many different rate structures are used across utilities. Thus, some normalizing assumptions are needed to enable a comparative analysis. Approximately 47% of utilities surveyed use increasing block structures. The unit price of water increases with increased usage to encourage conservation through a price signal. A uniform rate structure – constant price per unit volume – is used by 29% of surveyed utilities. Eighteen percent of utilities offer decreasing block structures, defined by decreasing unit prices of water at certain usage blocks, and 6% reported other structures such as flat fees. To facilitate a comparison across such structures, monthly residential costs are compared at the same volume of usage. This is also necessary from a purely

[4] Six of 341 utilities reported being private or investor owned. They were all combined water and wastewater.
[5] This includes eight reasonable exclusions: one utility with unrealistically high water use per capita (likely from significant water-intensive commercial operations), two utilities that reported rates of $0 and five utilities that reported zero million gallons of annual water sold.

practical perspective because the AWWA survey only reports the monthly residential charge for set volumes of 500 cubic feet (cf), 1000cf, 1500cf, and 3000cf. The EPA reports that the average family of four uses 400 gallons of water per day, or 100 gallons daily per capita (EPA, 2013). This is equivalent to 1100 cubic feet monthly use for a household size of 2.6, the average national size as reported in the US Census 2010. The average user in the AWWA dataset consumes 133 gallons a day, approximately 1400cf monthly for a household size of 2.6 or 2100 cf for household size of four. For this analysis ***1500 cubic feet is selected as the standard usage for comparison***. Eighty percent of utilities (10th-90th percentile) consume between 900 and 2100 cubic feet per month. It is important to note that non-residential commercial use (non-industrial) cannot be clearly separated from total reported non-industrial use, and as a result the daily per capita use may be a slight overestimation. On average, fewer than 10% of the accounts are non-residential and since industrial use is excluded, particularly large or water-intensive users are unlikely to distort data[6]. Since 1000cf monthly could arguably be an equally valid assumption for average use, analyses are repeated for lower consumption levels of 1000cf and 500cf in some instances.

The Analysis

We seek causal relationships between a network of factors that influence water rates and explain their variability across the nation. A network diagram of key factors is proposed in **Figure 4.** The four cost and demand drivers shown are hypothesized to determine financial factors such as debt and operation expenses. Operation expenses and debt represent the bulk of costs for most utilities, as such they are proposed as strong drivers of water rates. In addition to considering how cost and demand factors may influence rate drivers, we explore whether there is a significant correlation between the costs and demand factors themselves. For example, we would expect population and utility size to be well correlated; we investigate this and other potential correlations in the following sections.

[6] One utility with unusual per capita usage (>500 gallons daily) is excluded from the analysis.

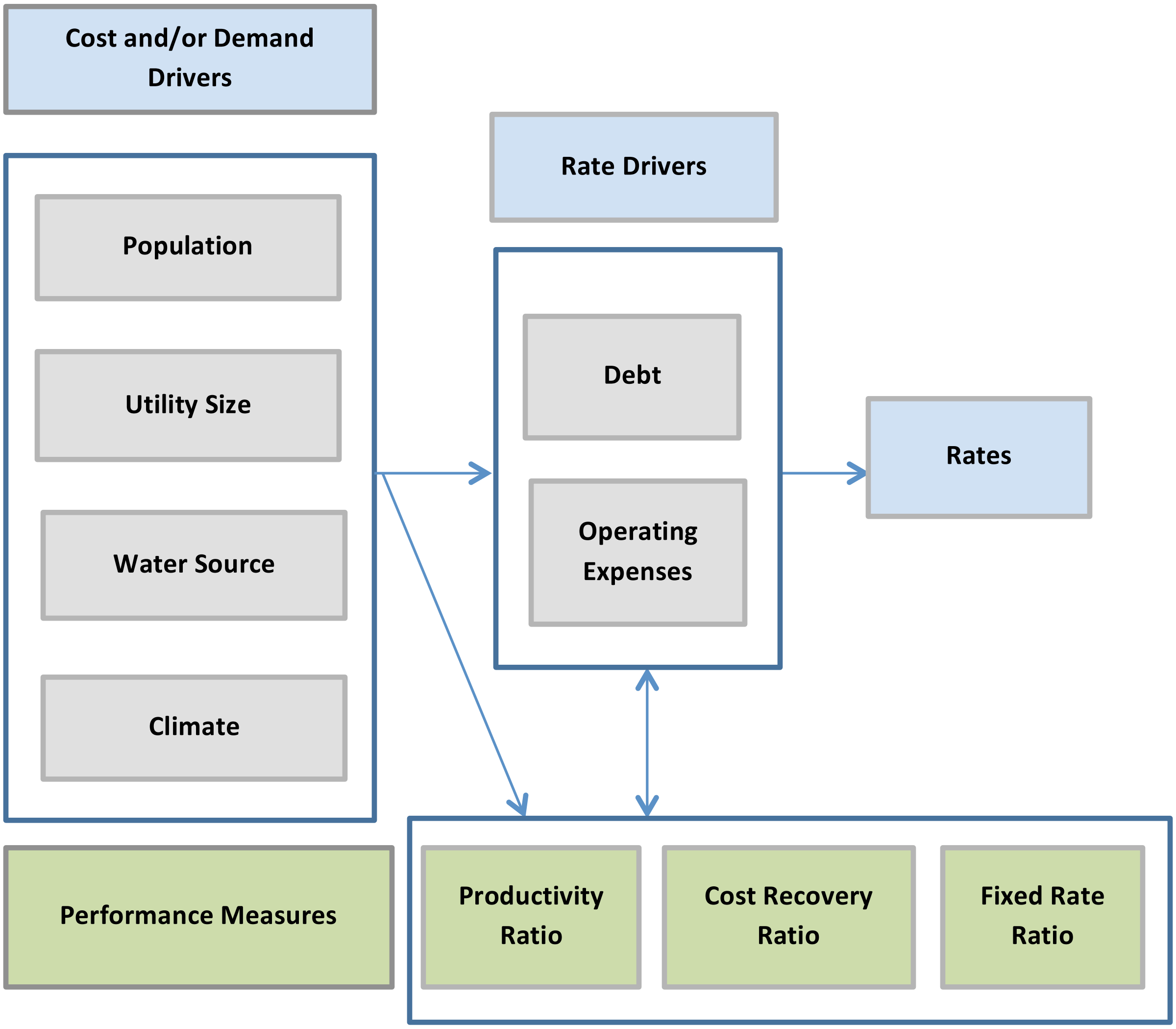


Figure 4: Proposed conceptual Structure of relationships between rate drivers and performance metrics

In addition to quantifying the hypothesized relationships, the analysis also defines three performance measures that provide general indicators of a utility's operational productivity, its financial efficacy (i.e. ability to recover costs), and sensitivity of its revenue stream to consumer behavior. These performance measures were selected because of their potential to provide additional insight and based on the available data. The following section outlines definitions and motivations for these indicators.

Performance Measures

An efficient rate is one that recovers operating expenses and debt in a manner that balances revenue stability with the need for equity and maintaining price signals (Beecher, 2010). The first requirement, recovering costs, is addressed by two performance metrics defined below and centers on interpreting the relationship of water rates to debt and operation expenses. The second requirement, maintaining equity and price signals, is part of the more complex rate and policy setting mechanisms that varies greatly between utilities and is not directly addressed in this paper.

The Cost Recovery Ratio (CRR) compares the revenue utilities generate from residential customer rates to the costs incurred for supplying the water. Typically costs fall under three categories: operating expenses, debt service (annual payments on loans), and interest expense (interest on loans). In this analysis we are limited to variables reported in the AWWA survey (see Appendix A for comprehensive definitions) and, unfortunately, annual debt service payments are not explicitly reported. Therefore we can only accurately quantify operating expenses and interest expense, and the metric is defined as follows:

$$Cost\ Recovery\ Ratio\ (CRR) = \frac{Monthly\ Residential\ Charge}{Operating\ Expenses + Interest\ Expense}$$

Both the residential charge and the expenses in the equation above are for 1500 cf/month.

In addition to the volumetric rate structures, most rates include base charges and other fixed fees that are applied to the account regardless of consumption. A high base charge helps utilities reduce the variability of incoming revenue, but may also be politically unpopular, place a higher burden on low-use customers, and reduce the effectiveness of the price signal for conservation (Beecher, 2010). In August 2012 Circle of Blue reported that Austin, TX, Charlotte, NC, and Las Vegas, NV had all increased their fixed fees in the past two years. Conversely, Lubbock, TX actually plans to lower its fixed fees by 75% in the next three years citing concerns that they place too high a burden for low-income users; instead charges will increase on high volume users, despite fears surrounding the financial robustness of such a move. Many fixed fees are directly related to infrastructure costs, such as the $5 charge in Las Vegas to pay for a new supply tunnel from Lake Meade (Walton, 2012). Other utilities adopt creative rate structures that attempt to solidify the link between revenue and cost of service, such as the stormwater charge applied by the Philadelphia Water Department. To quantify some of these pricing dynamics and associated revenue stream impacts, the Fixed Charge Ratio (FCR) is defined as follows:

$$Fixed\ Charge\ Ratio\ (FCR) = \frac{Fixed\ Charge}{Total\ Charge}$$

The CRR and FCR together provide a picture of cost recovery and revenue stream reliability.

The Productivity Ratio, a measure of operational efficiency, is the third performance metric defined here. No breakdown of operating expenses is included in the AWWA survey data, but a proxy variable for labor, often the largest component of the operating budget (Raftelis, 2005), is computed as follows:

$$Productivity\ Ratio\ (PrR) = \frac{Annual\ Water\ Sold\ (Million\ Gallons)}{Number\ of\ Full\text{-}time\ Employees}$$

The PrR metric reflects the efficiency of a utility, but also the inherent labor intensiveness of different processes.

A. Operating Expenses & Debt

Operating expenses and debt are proposed as rate drivers, since we expect these two broad categories to account for almost all of a utility's expenses (**Figure 4**). To make meaningful comparisons across utilities of different sizes, key variables are normalized with respect to volumetric output. For example, operating expense is divided by the total annual volumetric output of the utility and, in some cases, additionally converted to a monthly operating expense for 1500 cf for direct comparison to rates. The same is done for other financial variables resulting in the following eight normalized variables: operating expense per million gallons of water sold (WS), operating expense per 1500cf of WS, debt per million gallons of WS, debt per 1500cf of WS, assets per million gallons of WS, assets per 1500cf of WS, capital needs per million gallons of WS, and capital needs per 1500cf of WS. Detailed definitions of the original (un-normalized) variables as provided in the AWWA survey can be found in Appendix A.

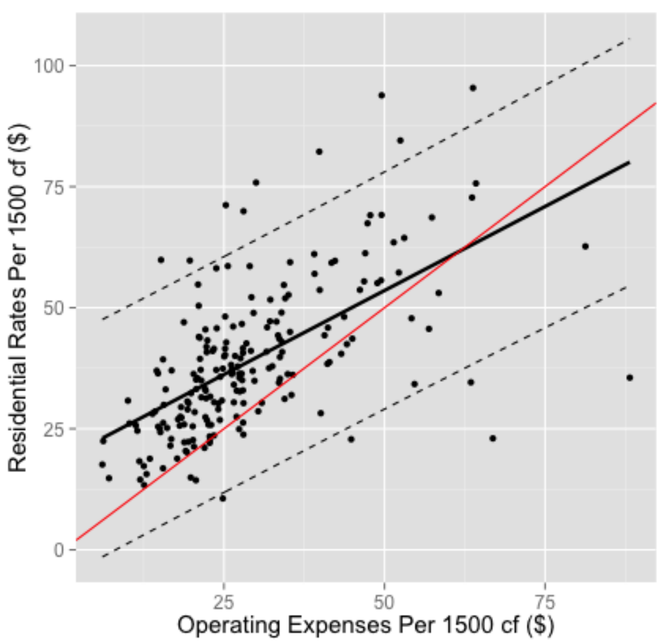


Figure 5: Residential rates (per 1500cf) show a well-correlated relationship with operating expenses.

Figure 5 shows that operating expenses are well correlated with rates. Utilities above and below the 95% prediction interval represent outliers from the fitted relationship. Perhaps even more interesting are the utilities that lie below the 1:1 line (in red), indicating that revenue from rates alone does not recover the operating expenses associated with the production of the water provided, let alone the cost of any long-term debt.

Possible factors associated with these outliers include disproportionate cost recovery from non-residential users (i.e. wholesale, commercial, industrial), and heavy reliance on income from property taxes or new connection fees. Aurora Water, in Colorado, is a high outlier; it receives no revenue from taxes or any of the city's general funds, has extensive conservation efforts, and of the $33.8 million in expenditure for all Aurora city funds, $18.3 million are being spent for capital improvement projects directly related to water supply for which the rate payer is then directly responsible. Two other high outlier utilities, Albermarle, Virginia, and Fox Chapel, Pennsylvania, both purchase water from other service authorities. This suggests that outsourcing production might bear an additional cost, a hypothesis investigated in more depth in Section C. While high outliers have some of the highest rates, they are also all above the 1:1 line, indicating that these high rates are closer to the true cost of producing the water. Prince William County Water Authority, in Virginia, is a low outlier (discussed in Section D), which may be partially attributable to a heavy reliance on new connection fees that allows rates to lie well below cost-recovery level.

Debt is more difficult to quantify than operating expenses given the limited data reported in the AWWA survey. Long-term debt normalized by volume is a comparable metric to that used for operating expenses, but it fails to recognize some characteristics unique to debt. In particular, it is important to recognize that utilities take on debt at different points in time so long-term debt reported in a single year can vary depending on the fraction of the loan that has already been repaid. One measure of the extent to which water utilities rely on borrowing is their debt ratio, calculated as the utility's long-term debt divided by its total assets. The higher this indicator, the more a utility relies on borrowing to support investment in capital needs. The nature of the water industry lends itself to high debt because fixed assets represent a much larger cost than operating expenses (on average 5:1) (Beecher, 2010), so they almost always carry the costs of past capital needs. Similarly, it is important to acknowledge that a low debt ratio does not necessarily indicate financial security the way it might in other businesses, since utility assets cannot be easily sold off and, barring a large population shift, a drinking water service must remain in place in some form (Lewis, 2012). Both debt ratio and debt per volume are used in our analysis. It is very important and informative that future surveys include debt service, the annual amount of debt repayment a utility owes. Debt service is typically the value that directly informs rate setting and a much stronger correlation would be expected in this case.

In **Figure 6** the correlation of rates and long-term debt has Pearson's r of 0.39. A number of utilities have zero debt, and while rates generally increase with debt, there is high variability. Much of this variance may be due to utilities being in different stages of loan repayment, or systematic differences in utilities taking on debt. Of the utilities that reported long-term debt in the AWWA survey, 13% reported having no long-term debt at all, while some had long-term debt several times their annual operating expenses. Not all utilities can obtain the financing required or push rate hikes through political and legal barriers in order to meet their

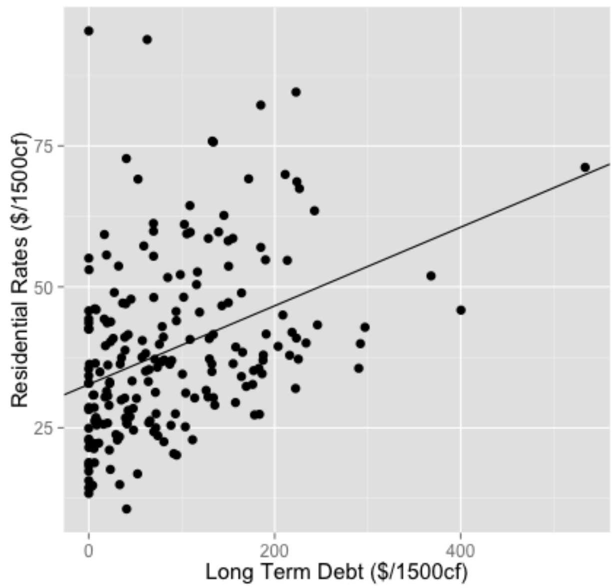


Figure 6: Rates and long-term debt show a weak increasing trend and many utilities, across the spectrum of rates, holding no debt.

infrastructure needs. Conversely, some large utilities overestimate demand growth and incur very large debt from over-ambitious capacity development. Tampa Bay Water, FL built a desalination plant that is rarely operated at capacity because of the high operational expense and decrease in customer demand. This decrease is attributed to conservation efforts stimulated by the increase in rates associated with debt service obligations from the plant and related infrastructure development. A one billion dollar desalination plant in Carlsbad, CA recently broke ground facing similar concerns; it is possible that water-scarce California, which has already implemented widespread water conservation efforts, proves to be the place where such sources may be economically viable with support for higher rates. The Metropolitan Water District of Southern California estimated that in 2024 water from the desalination plant will be less costly than from other more traditional sources such as ground and surface water (Barringer, 2013). In subsequent sections, we will show that large utilities are more likely to incur large debt for such projects and that small utilities typically have lower debt despite higher capital needs. For large investments to boost supply, new treatment facilities, or urgent replacement of aged pipes, a pay-as-you-go approach is unlikely to work, but some utilities, among them the Chicago Water Department, have successfully adopted this approach to paying for replacing aging pipes before they reach a critical point.

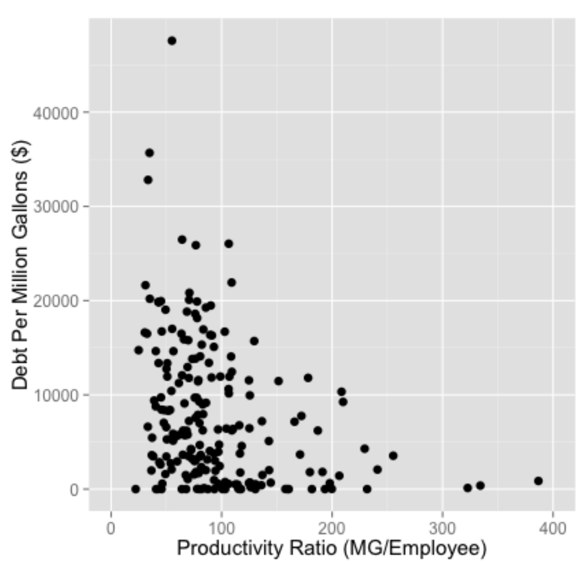


Figure 7: Operating expenses and the Productivity Ratio show little trend at low productivities.

The Productivity Ratio (PrR) adds another layer of insight to operating expenses and debt. At productivity above 100MG/employee, operating expenses decrease with improved employee efficiency, but at lower productivities operating expenses vary widely (**Figure 7**).

productivity may suggest that factors other than labor impacts operating expenses, since the

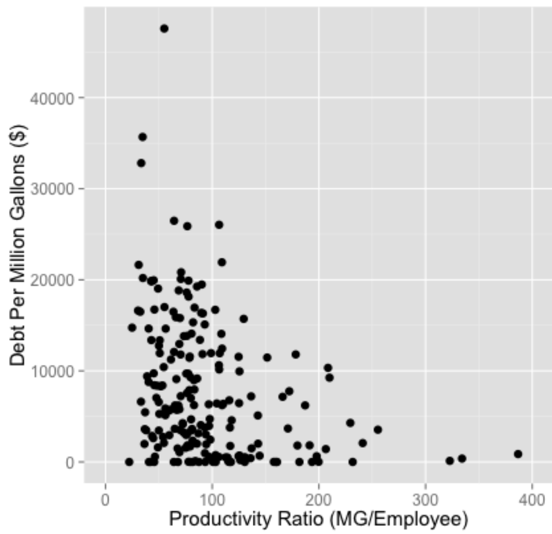


Figure 8: Many utilities at high productivity have low long-term debt.

variability in labor costs alone would likely not be enough to explain such a wide spread of operating expenses. When other costs, such as energy or other fixed process costs, drive operating expenses, there may be fewer savings associated, and thus less emphasis on, efficient labor. Furthermore, it establishes that the most expensive utilities to operate are not expensive solely, or even primarily, because of high labor costs. Analysis in Section C will highlight the importance of utility size in further explaining this trend. Plotting debt and the productivity ratio is also interesting. Utilities with low productivity (less than 100MG/employee annually) have a wide range of debt levels (from 0 to the highest debt of reported by any utility). Above this level of efficiency debt levels are lower and decrease as efficiency improves (**Figure 8**).

Analysis of the survey data for operating expenses and debt reveals a slightly more complex picture than originally expected. We confirm a significant correlation between operating costs and rates, but significant variation suggests the presence of revenue sources outside rates and/or varying efficiency in matching the costs of residential water exactly to revenue from residential water. The debt-rate relationship is more nebulous; as discussed in the previous paragraph this does not indicate the absence of a relationship, but rather the difficulty in translating the provided debt variables in the AWWA survey (long term debt and debt ratio) into the debt values used in rate setting (debt service). There are some preliminary indications that savings can be made by improving the efficiency of a utility as measured by the PrR; however utilities with very low efficiency exhibit a wide spread with no trend, perhaps suggesting that some processes are inherently more expensive than others regardless of efficiency improvements.

B. Water Source

The two primary sources of freshwater in the U.S. are groundwater and surface water from lakes or rivers. **Figure 9** illustrates the geographic distribution of the utilities and their corresponding water source.

Surface water was the primary source for almost 50% of utilities, and groundwater was the second largest source. Utilities with split sources are defined as those that do not depend on a single source for more than 60% of their supply. Only 6.7% of utilities engage in this extent of supply diversification. Forty utilities that purchased water from larger utilities did not specify the source of the provider, and are considered a fourth category. In Figure 4 source was proposed as

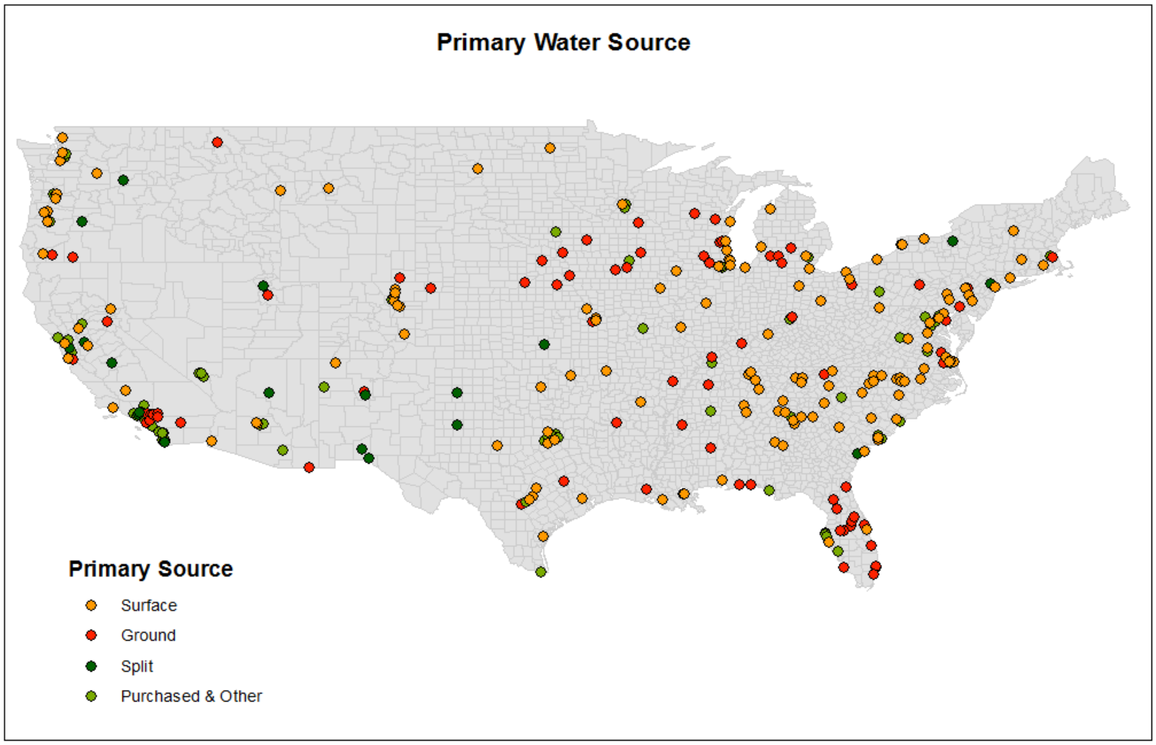


Figure 9: Primary Water Supply Source across the continental United States.

a cost and demand driving variable that in turn impacts rates; this hypothesis is well supported by the initial exploratory analysis and key findings include the following:

- **Rates for groundwater utilities are significantly lower than other sources.** The median groundwater rate is $30 compared to $37, $44, and $42 for surface, split and purchase/other respectively[7]. There is also smaller variability in groundwater rates.
- **There are systematic additional costs to source diversity.** Split source utilities have higher rates than both surface and groundwater utilities, a trend mirrored by higher minimum operating expenses for split source utilities compared to providers with a single primary source.
- **Many resale utilities balance the higher cost of purchasing water with lower debt.** The median debt ratio is under 0.5 for all sources, but utilities that purchase water have few utilities falling in the 0.5 to 1.0 range. Utilities that purchase water have median operating expenses approximately 40% above other sources.
- **Split source utilities have higher fixed revenues, uniformly high CRR, and higher productivity ratios** relative to other sources. With the exception of split utilities, the FCR ranges from 0 to approximately 0.5; all split source utilities, except one, have an FCR higher than 0.12 suggesting higher fixed revenues are being recovered from rates, perhaps in response to greater variability in supply costs. In addition, all but two split

[7] The above rate trends hold with lower use volumes (500cf and 100cf) with only slight distortion from possible systematic rate structure differences with different water sources.

source utilities have CRR above 1, compared to 13 surface water utilities and 17 groundwater utilities. Lastly, the median productivity ratio for split source utilities is 93 MG per employee annually, approximately 15 MG higher than the ratios for all other utilities.

- **Surface water utilities have the highest CRR**, particularly in the top 50% of utilities. This suggests that many are recovering in excess of costs to pay for debt service or pay-as-you-go capital improvements.
  Note: Additional supporting figures for the conclusions above are provided in Appendix C

Utilities use the least expensive source to its limit and then move up the cost curve. This helps explains the systematic higher rates and expenses for split source utilities. Tampa Bay Water, FL turned to surface water projects when lowering aquifer levels endangered the longevity of groundwater operations. Other utilities that may not have adequate surface supplies (or the rights to them), must invest in expensive new groundwater pumping infrastructure, or other alternative sources in the near future to expand their supply. This was the case for the Orange County Water District, CA that in 2002 invested $350 million dollars in an aquifer recharge project using water from the Santa Ana River to protect its overdrawn aquifers from the threat of saltwater intrusion. Drought induced water scarcity in the Colorado River was a stimulus.

There is a delicate balance between revenue stability and conservation pricing structures, particularly for utilities in arid climate. In 2010, following a rate increase and the adoption of an increased block structure, Austin Water, TX projected an $11.1 million increase in revenue. Instead, an especially high rainfall year resulted in a $38.1 million loss in revenue since fewer users fell into the high consumption rate bracket, largely because of decreased outdoor water demand. To reduce the risk of such an occurrence in the future, Austin Water increased the Water Sustainability Fee, a fixed charge, from 11.8% to 19.6% of their total water revenue in 2012.

Differences in the cost curve help rationalize evolving approaches to balancing revenue stream stability with maintaining price signals through blocked rate structures. If the cost curve is steep, such as it might be if moving from a surface water source to desalination, conservation is often a preferable option, but barring mandatory conservation rules, the most common mechanism is to implement an increasing block rate structure. Consider a 2010 report by the Equinox Center that reported desalination in San Diego County, CA to have the highest marginal cost of any alternative at about $1,800 to $2,800 per acre-foot. While groundwater and surface water do not have sufficient capacity for this county, their marginal costs were estimated at $400-$800 per acre-foot and $375-$1,100 per acre foot, respectively. Ultimately, conservation was recommended as the least expensive and most feasible approach, and previous research into the efficacy of rate structure changes as the approach to implementation was cited.

It is interesting to speculate on the reasons for the systematically lower rates of groundwater utilities. On average surface water utilities have 40% greater debt, but only 20% greater assets than groundwater. This might suggest that, in some cases, surface water capital infrastructure is simply more expensive than groundwater.

C. Utility Size

As noted earlier, utility debt, operating expenses, and average capital needs are normalized by annual water production to allow for comparisons across all utility sizes. As briefly mentioned in Section I, the AWWA survey classifies utilities in three size categories; **small** utilities producing less than twenty million gallons of water daily (MGD), **medium** utilities producing between 20 MGD and 75 MGD and **large** utilities producing more than 75 MGD.

In the network diagram (Figure 4) utility size was proposed as a variable that could influence both debt and operation expense, and consequently influence rates. It was found that average rates were similar across different sizes, but with a larger range for small utilities. Despite no significant correlation between size and median rates, our analysis highlights important scale effects in utility productivity as well as differences in capital investment needs and rate recovery behavior. The key findings are summarized as follows:

- **On average, small utilities have the highest operating expense and are the least likely to recover costs through rates.** The middle fifty percentile of operating expenses for small utilities ranges from \$1900 to \$3400 per Million Gallons (MG), compared to \$1600 to \$2600 for medium, and \$1800 to \$2500 for large utilities, highlighting the existence of economies of scale. Twenty-five percent of small utilities have CRR below 1, compared to 10% for medium utilities and 19% for large utilities.
- **On average, small and medium utilities have lower average debt, but this comes from mixing a very low and a very high debt group.** The median debt ratio for large utilities is 0.42 compared with 0.30 and 0.28 for medium and small utilities, respectively. However, the bottom 50% of small and medium utilities have little to no debt, while many small and medium utilities carry higher debt than any of the larger utilities.
- **Small utilities are both the most and the least labor-intensive utilities.** The 25th to 75th percentile range for the PrR is 51 to 110 MG per employee for small utilities, compared to 72 to 116 for medium utilities and 70 to 101 MG for large utilities. **Figure 10** shows the spread shown earlier in Figure 6 with utility size additionally indicated.

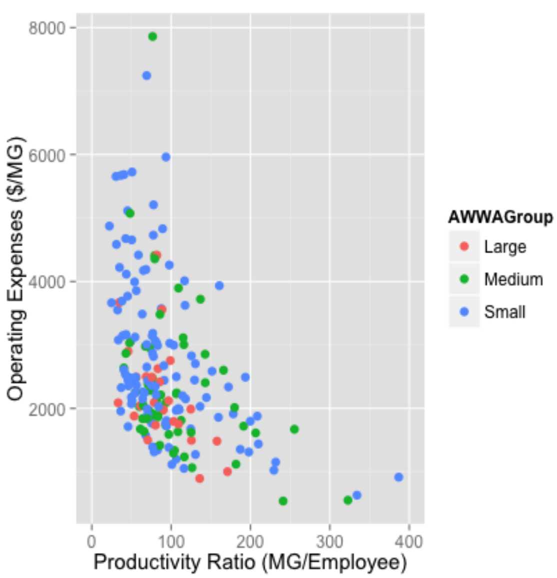


Figure 10: The most and least labor-intensive utilities are small (in blue).

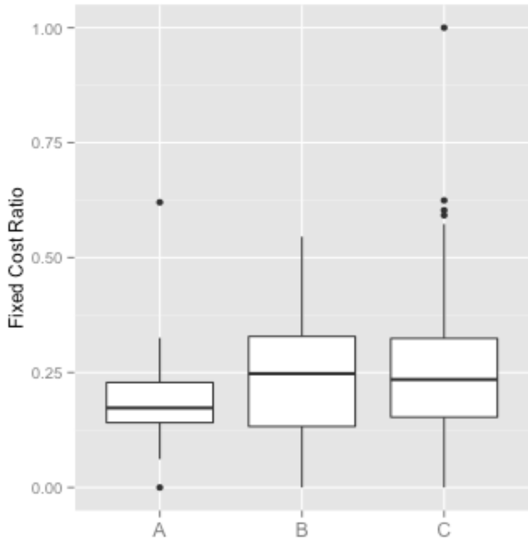


Figure 11: The fixed cost ratio, the fraction of revenue from charges independent of volumetric use, is much lower for large utilities (box A on the left). *Utilities with annual productions about 50000 MG are excluded from the figure

- **Large utilities more frequently recover full costs through rates, have more debt commitments, and the lowest fixed charges.** All large utilities have a CRR above 0.9, indicating little dependence on revenue from sources other than rates; small and medium utilities make up the majority of utilities with a CRR below one, a value suggesting rates inadequately represent the true cost of service. No large utilities report zero debt, compared with 8% of medium utilities and 18% of small utilities. Interestingly, large utilities have lower median and range of FCR indicating that they derive a larger fraction of their revenue from consumption-related variable charges (**Figure 11**).
- **Large utilities are overwhelmingly surface or split source utilities.** This is particularly true of utilities with annual production volumes over 10000 MG (**Figure 12**).

Note: Additional supporting figures for the conclusions above are provided in Appendix C

The trends with utility size suggest a very different status quo for large and small utilities despite similar rates at first glance. They suggest that a majority of large utilities are setting rates that reflect operating costs, while small utilities vary widely in their ability to do so. Small utilities may depend more closely on outside revenue from property taxes and other fees, or face more political difficulty or equity concerns to raising rates. This is an interesting observation given the low debt held by many small utilities in contrast with the very high debt held by other small utilities. In some instances this debt gap may indicate a true difference in infrastructure needs. An open question is whether utilities with little to no debt could actually be at higher risk than those with more debt. Their financial climate may lead to delays in needed infrastructure investments and cause service reliability issues. Based on pipe age and average

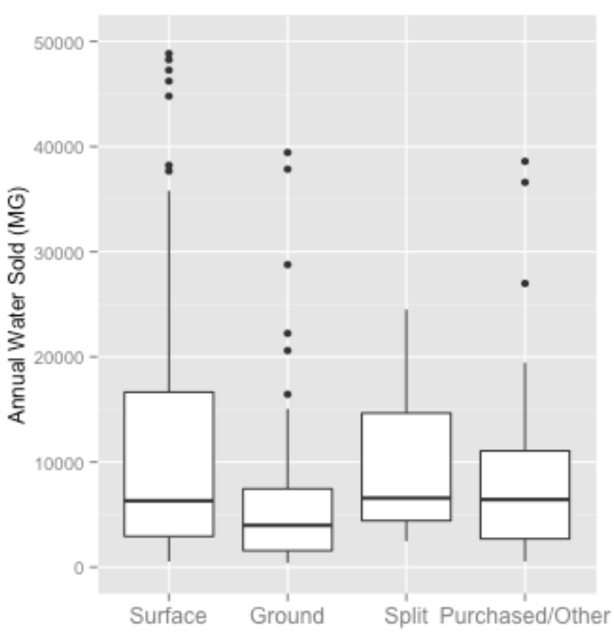


Figure 12: Annual Water Sold (MG) by Primary Source
*Utilities with annual productions above50000 MG are excluded from the figure

population it was forecast that the smallest utilities could see annual water bill increases of up to $550 a year, compared to only $75 for the largest utilities, partially because smaller utilities tend to have much higher pipe per capita ratios (AWWA, 2011). A counterpoint could be that the smaller utilities represent areas with little population growth and the low debt reflects the ability of the communities to maintain a vintage system adequately through property tax revenue. However, the published literature does not directly support this viewpoint.

Consider the Moline Water Department in Illinois which has an annual operating budget of only $8.8 million, but an initial estimate of the costs of needed infrastructure replacements is an astounding $240 million. Their current debt stems from a $25 million treatment plant completed in 2005, and smaller (< $3 million) investments in UV disinfection pilot, meter installation, and new storage tanks. Most significantly the Moline Water Department has already experienced a number of failures from old cast iron main pipes and still has sub pipes that do not meet water quality requirements; the replacement of their distribution system is their most urgent cost, and represents an estimated $183 million of the $240 million sum.

D. Population

Population characteristics – total, density, and median income – are possible demand and cost drivers. Not surprisingly, total population correlates very strongly with utility size (Pearson's r = 0.94) so the findings discussed in the previous section with regards to utility size may also be interpreted as associated with population. Population density is a strong predictor of service population. In other words, small utilities are rural or suburban while many large utilities are more likely a mix of urban and suburban areas. Variations from this pattern falls significantly along geographic lines - both small and large utilities in the West tend to serve less dense populations than utilities in other regions as seen by the concentration of Western utilities in the highlighted area under the line of best fit, indicating that for a given population they have a lower than average

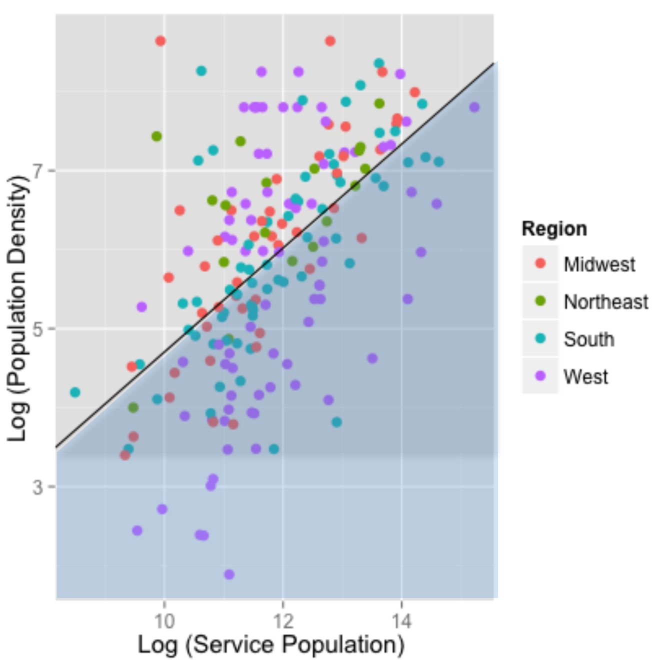


Figure 13: The population density and service population are shown on a log scale. Many utilities in the South and West have lower population densities than similar population counterparts in the Northeast and Midwest. The shaded area represents utilities with sparser populations (i.e. lower densities compared to total population).

population density (**Figure 13**). This is significant because additional costs are associated with delivering water over a larger area. There is no significant correlation between median income and rates or operating expenses. This suggests that difference in operating costs as result of labor are not particularly sensitive to demographic differences in income level, especially in comparison to the strong correlation with the productivity ratio.

Quantitatively, our analysis shows few population specific trends independent of utility size. Regardless, it is useful to summarize some of the challenges posed to utilities by population growth and/or decline. Areas of growth benefit from the additional income of new service fees, but at the cost of capital expansion and potential supply stress from increased demand. On the other end, the stagnation or decline of population necessitates revenue shifts towards rates as new connection fees decline. The Prince William County Service Authority (PWCSA) in Virginia saw their revenue from new developer fees drop 32% from 2009 to 2010 and another 16% from 2010-2011. Interestingly, the two years of steep decline was countered by a 57% rise in connection fees from 2011 to 2012, from a few new developments. Before 2009, new developer fees accounted for 22% of total revenue (PWCSA, 2009-2012). There are few associated capital savings since many utilities in areas of declining population still face aging infrastructure in dire need of replacement. Low-density areas require more piping per customer, typically at a greater capital and maintenance cost (AWWA, 2011). Income is also an important factor in determining the affordability of water rates, though it is not considered as such in this analysis.

E. Climate

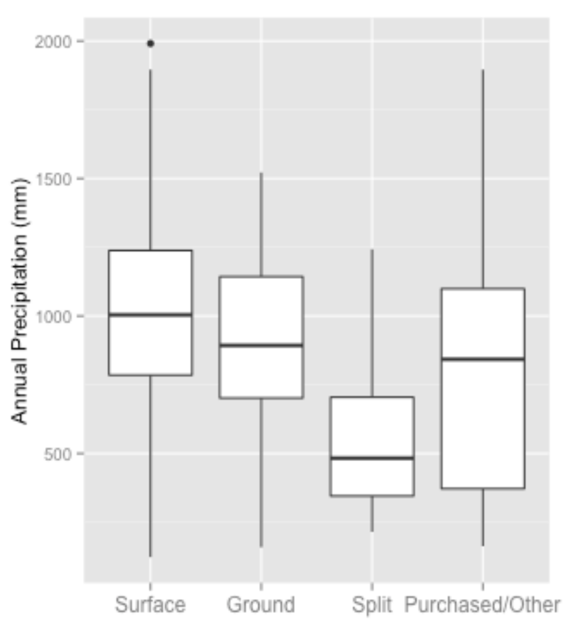


Figure 14: The average annual precipitation of utilities with split sources has a significantly lower median (black middle line) and 25th to 50th percentile range (white box) than surface and ground water utilities.

Four climate variables – average temperature, average precipitation, temperature variance, and seasonal precipitation – are considered in the climate attribute analysis (see Appendix B for definitions). They potentially drive rates by impacting operating expenses and debt. No particularly strong relationships directly with water rates, operation expenses, or debt with the exception of a weak trend between operating expenses and temperature variance are found. A significant and interesting climate trend is that **split source utilities have the lowest average annual precipitation** (Figure 14). This is in line with earlier analysis suggesting that resource constraints move utilities towards supply diversity, to increase their supply reliability and meet increasing demand. Despite no unifying correlation between climate and expenses or rate and climate, climate can be a key cost driver in water scarce scenarios, as is illustrated by the City of Santa Barbara, CA's water practices. The City has annual rainfall just under 500mm. To reduce dependence on its potentially volatile allocation from a reservoir on the Santa Ynez River it has a desalination plant and recycling water facility (for non-potable use), treatment methods that are almost always more expensive to operate per volume of water sold than traditional surface or ground water sources. Furthermore, because they heavily emphasize conservation (their per capita use has dropped 25% since 1988) they must charge more per volume of water to recover the costs of the water sold and distributed. Significantly, the desalination plant was built in response to a severe drought from 1989 to 1991 and is in "long-term storage mode" and will only be reactivated when demand can no longer be met with existing supplies (City of Santa Barbara, 2013).

F. Summary

The factors impacting rates are complex and highly interrelated. **Figure 15** displays the relationships between factors discussed in the analyses in Sections A-E in context of the initial conceptual diagram (Figure 4). The relevant sections for each individual factor-to-factor or factor-to-rate relationship are labeled for the reader to reference, but all the results of the exploratory analysis are not reiterated here. Rather, we consider some broader conclusions across the sections.

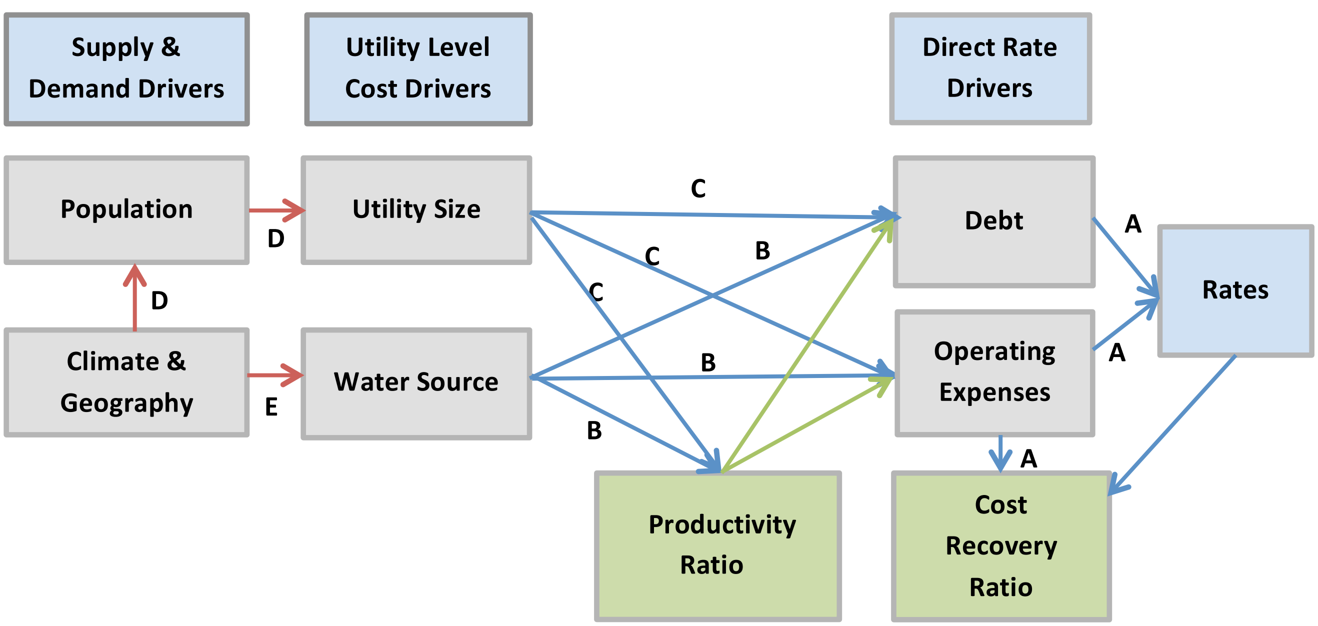


Figure 15: Conceptual Causal Network

Climate has significant impacts on costs and rates where annual precipitation is low, and in regions where groundwater and other resources are used to meet increasing demands. When utilities are forced to move beyond the cheapest source to provide sufficient and reliable service, the higher productivity ratios observed suggest that the importance of efficiency rises. This is also accompanied by higher cost recovery, indicating that in such a setting utilities approach a level at which the customer is paying for the cost of delivering the water they use. The implications of water scarcity, while perhaps more visible in the West, extend beyond these boundaries. Desalination plants, an indication of supply shortages and a controversial energy-intensive and very expensive solution, are increasingly present in the US. In 2005, of the one hundred largest desalination plants operating or planned for construction in the world, six were in California, five in Florida, four in Texas, and one in Puerto Rico (Gleick, 2006). Desalination plants in the Northeast began with the opening of Cape May New Jersey in 2000 and other towns, such as Brockton, Massachusetts, have followed suit.

Utility size is an interesting determinant of performance. If simple economies of scale held, then small utilities would on average be more expensive to operate on a volumetric basis and thus charge higher rates. The reality is not quite this simple. On average smaller utilities have the highest operating costs, but this is not necessarily reflected in the rates. In fact, on average, the rates for each size group are similar, but rates for smaller utilities extend across a wider range. A similar wider range is seen in the analysis of debt. Smaller utilities account for both the highest and lowest debt. Smaller utilities do not seem to recover the cost of water to the same extent as large utilities reflecting dependence on other revenue sources and less revenue available for any potential investment needs.

III. Multivariate Analysis

In the previous section, pairwise relations between selected attributes were explored. This section explores the combined impact of potential factors on water rates, and their associated cost recovery. A hierarchical clustering algorithm is used to split the utility rates at automatically determined thresholds of designated variables in order to maximize the contrast between the resulting groups. The analysis results in the identification of six rate groups ranging from eight to fifty-two utilities. Each groups represents a range of rates (that can overlap) with a different combination of primary drivers. Once the groups are isolated, three characteristic values – the 25^{th}, 50^{th}, and 75^{th} percentile – of the key attributes explored in Section II are summarized.

For this analysis, almost the same subset of utilities is used as in the previous section. Eleven additional utilities are excluded because they do not report values for every variable, and the algorithm cannot use incomplete sets of variables. The method applied here is the model-based recursive partitioning method, run in the R package ‘party’. Using measures of parameter stability, it splits the utilities into clusters with similar rates based on the most important predictor characteristics (see Appendix D for detailed methodology and reference texts). To limit the effect of variable interactions, the following eleven variables were chosen to be included as potential partitioning variables:

Water Source
Rate Structure
Water Sold Per Employee
Debt Ratio
Annual Water Sold
Seasonal Precipitation
Annual Precipitation
Average Annual Temperature
Temperature Variability
Median Income
Population Density

Operating expense per MG is excluded, despite it being a strong individual predictor, because it is highly correlated with water sold per employee and primary source, which are more informative cost and demand variables. The model was run with both debt ratio and debt per MG (but not both at the same time since they are heavily correlated). The model split into more groups with the use of Debt Ratio so it was kept as a partitioning variable while debt per volume was left out. As the results show, debt per volume is still significantly different across many of the groups even though it is not explicitly used as a splitting variable. Like operating expenses, debt differences can often be explained by other factors such as utility size or source and it can be more informative to interpret these direct utility attributes than the more complex financial variables.

Figure 16 summarizes the results of the multivariate rate grouping of utilities. Six groups, A through F, are identified in addition to the key splitting variables and splitting values for each node of the grouping tree. The first splitting variable is source; since operation expenses are not modeled directly this indicates that water source differentiates rates most strongly compared to any other driving factor. The remaining group of utilities (groundwater excluded) split first on productivity. In particular it identifies very low productivity as a link to high rates. The remaining utilities then split on temperature variance, debt ratio, and finally utility size.

Table 1 reports the 25th, 50th and 75th percentile for all variables discussed in the exploratory analysis in Section II. For each value reported, it highlights the highest group in yellow and lowest group in green. If the difference between two or three groups is not significant, several highest and lowest groups may be indicated. If there is only one group with a significantly different quartile range then only that group will be highlighted as either a minimum or maximum. Unless otherwise indicated each cell contains the 25th, 50th and 75th percentile in that order, with each value separated by a slash.

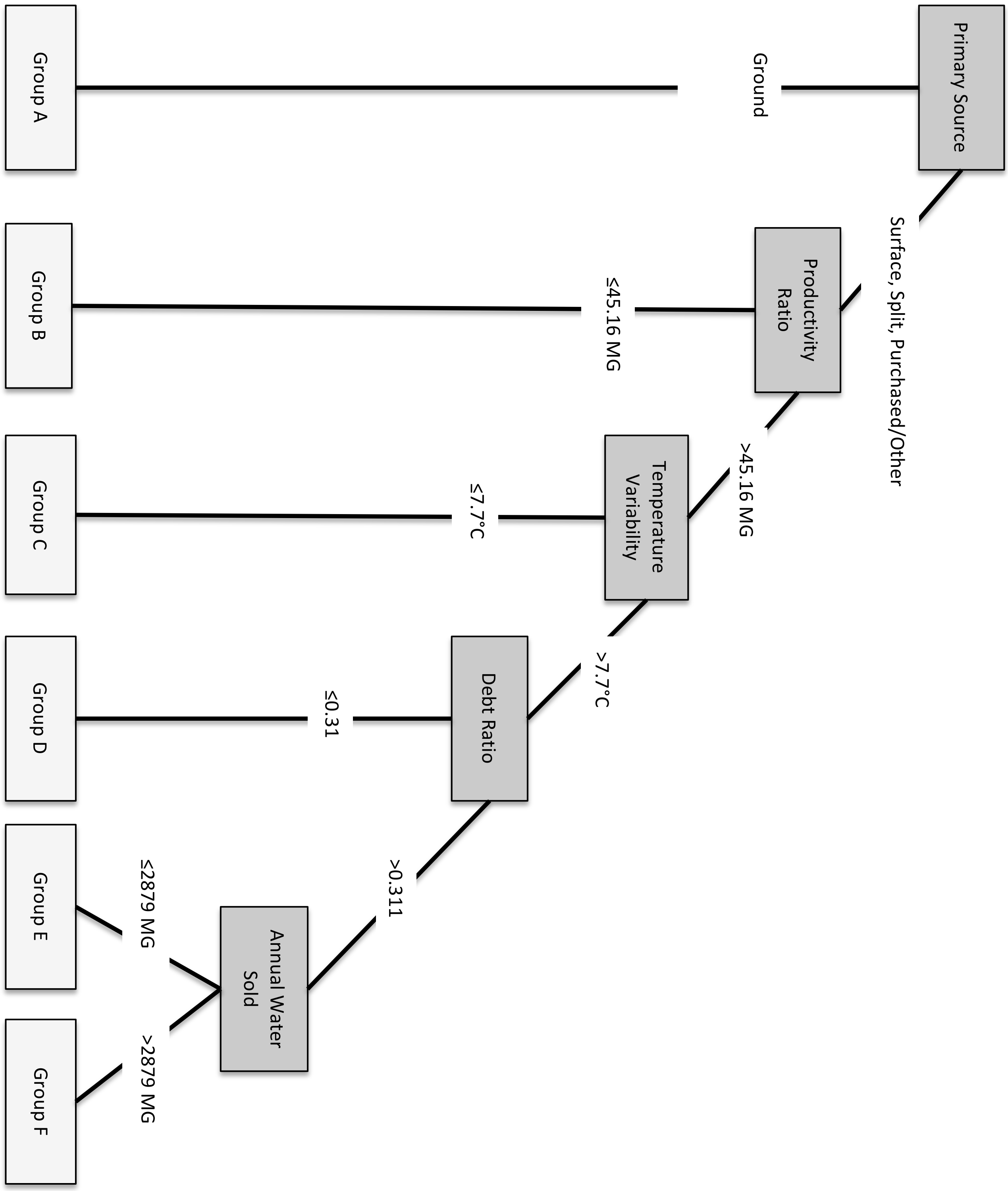


Figure 16: Multivariate Analysis Results

Table 1: Summary of Group-Level Quantile Values

Group	A	B	C	D	E	F
Number of utilities	52	16	26	45	8	34
Rates						
Rates ($) 1500 cubic feet	24 / 30 / 37	49 / 59 / 70	27 / 44 / 53	26 / 32 / 36	54 / 58 / 62	31 / 39 / 43
Rate Structure *(U/IB/DB/Other)*	12 / 22 / 18 / 0	4 / 7 / 5 / 0	7 / 14 / 1 / 4	16 / 18 / 7 / 4	4 / 0 / 4 / 0	8 / 17 / 9 / 0
Rate Driving and Other Financial Variables (all in $1000s)						
Operating Expenses Per MG	1.6 / 2.0 / 2.5	3. 0 / 3.7 / 4.6	2.8 / 3.8 / 4.4	1.7 / 2.0 / 2.3	2.4 / 2.6 / 3.1	1.8 / 2.0 / 2.5
Debt Ratio	0.13 / 0.26 / 0.46	0.20 / 0.35 / 0.50	0.15 / 0.28 / 0.44	0.12 / 0.20 / 0.25	0.36 / 0.55 / 0.62	0.41 / 0.49 / 0.62
Debt Per MG	1.3 / 3.5 / 10.8	8.0 / 14.0 / 20.0	1.8 / 6.2 / 12.3	9.6 / 3.0 / 5.9	9.4 / 11.2 / 12.9	7.2 / 10.9 / 16.7
Assets Per MG	14.5 / 21.0 / 34.5	38.8 / 49.7 / 57.2	22.0 / 27.1 / 29.8	13.4 / 24.8 / 36.9	15.1 / 25.5 / 33.4	17.8 / 27.4 / 112
Capital Needs Per MG	0.82 / 1.3 / 2.0	1.3 / 2.2 / 3.5	0.80 / 1.4 / 2.0	0.72 / 1.1 / 1.6	0.94 / 1.7 / 2.2	1.1 / 1.6 / 2.3
Cost & Demand Drivers						
Utility Attributes						
Primary Source *(SW / GW / Split / Purchase & Other)*	0 / 52 / 0 / 0	11 / 0 / 1 / 4	8 / 0 / 4 / 14	34/ 0 / 3 / 8	8 / 0 / 0 / 0	24 / 0 / 6 / 4
AWWA Group (Large/Medium/Small)	5 / 11 / 36	1 / 2 / 13	4 / 9 / 13	6 / 18 / 21	0 / 0 / 8	9 / 14 / 11
Annual Water Sold (MG)	1750 / 4010 / 8050	1990 / 2590 / 4720	4390 / 7710 / 18200	3320 / 7540 / 16800	1020 / 1660 / 2280	6630 / 9600 / 32100
Median Income (Thou.$/Year)	42 / 47 / 54	42 / 50 / 66	49 / 60 / 62	43 / 51 / 61	41 / 44 / 51	41 / 47 / 54
Climate & Population						
Annual Precipitation	660 / 873 / 1134	989 / 1140 / 1243	372 / 473 / 1180	557 / 859 / 1120	1070 / 1230 / 1350	556 / 930 / 1110

Seasonal Precipitation Ratio	1.6 / 3.3 / 6.4	1.4 / 1.5 / 2.5	4.8 / 14 / 47	1.5 / 2.1 / 3.5	1.3 / 1.6 / 3.1	1.5 / 1.9 / 5.1
Average Annual Temperature	8.6 / 10.5 / 15.8	11.6 / 13.3 / 14.6	10.5 / 14.1 / 15.2	7.5 / 9.6 / 14.6	9.7 / 11.8 / 14.5	9.9 / 12.2 / 16.3
Temperature Variability	9.57 / 11.5 / 13.4	8.36/ 10.6 / 11.4	6.20 / 6.8 / 7.41	10.7 / 11.9 / 12.5	9.9 / 11.6 / 13.0	10.0 / 10.9 / 11.6
Service Population	48 / 75 / 180	62 / 93 / 140	96 / 180 / 460	65 / 110 / 340	13 / 37 / 44	140 / 280 / 760
Population Density	95 / 260 / 750	170 / 340 / 730	720 / 840 / 2400	140 / 390 / 980	54 / 140 / 330	230 / 470 / 1300
Performance Metrics						
Cost Recovery Ratio	0.98 / 1.2 / 1.4	1.1 / 1.3 / 1.5	1.0 / 1.1 / 1.3	1.1 / 1.3 / 1.7	1.5 / 1.8 / 2.5	1.1 / 1.3 / 1.7
Fixed Rate Ratio	0.15 / 0.25 / 0.32	0.082 / 0.16 / 0.26	0.14 / 0.25 / 0.33	0.17 / 0.23 / 0.30	0.18 / 0.22 / 0.31	0.15 / 0.22 / 0.31
Productivity Ratio (MG Per Employee)	62 / 82 / 110	35 / 39 / 41	67 / 77 / 86	77 / 93 / 130	51 / 73 / 110	71 / 80 / 110

In addition to detailed results, the following short descriptions of each group's characteristics synthesize conclusions from Figure 16, which indicates the driving rate factor, and summarizes additional group level differences highlighted in Table 1. Where possible, the direction and nature of the interaction between rates, operating expenses, debt, and other factors are expanded upon using conclusions from Section II:

- All **Group A** members are groundwater utilities. They have the lowest rates (along with Group D) and lowest operating expenses of all the groups, and have low to average debt ratio. The low expenses and low debt are drivers of low rates. The low rates additionally reflect very low cost recovery relative to other groups; about 25% of utilities have CRR below 1. Utilities with low CRR depend more heavily on income from sources other than rates, such as property taxes or new connection fees, or recover a disproportionate amount of revenue from industrial and commercial users. Though these utilities currently have low debt, the low CRR indicates less ability to recover revenue for additional expenses such as debt service should they need to invest in new or updated infrastructure in the future.
- **Group B** has the highest rates and highest operating expenses of all groups. Productivity ratios are smaller (almost half) than those for all the other groups. At a national scale, operating expenses were found to be variable at low productivity ratios, which weakened

conclusions regarding the productivity-cost link. Group B represents low productivity and high expense utilities suggesting that the cost-rate relationship may hold at lower efficiencies for this subset of utilities. Group B has average debt ratios and cost recovery ratios almost all above one; high cost recovery is essential for these utilities given that they have the higher capital needs by volume than the other groups. From a climate perspective Group B receives comparatively low rainfall and high temperatures.

- **Group C** has the third highest rates of all the groups driven by high operating expenses. It has a larger range of operating expenses relative to group B, but much higher productivity suggesting that other costs may drive the higher operating expenses in this group. Climate may influence the high operating expenses, for example, Group C has the lowest temperature variability (this is the variable on which the group split), highest seasonal precipitation ratio, and by far the lowest precipitation of any group. It also includes many utilities that purchase water from another provider and earlier analysis in Section II showed this to correspond with an increase in costs.
- **Group D** has the lowest rates with the exception of Group A. This is likely a combined result of low operating expenses and low debt. It has the most number of large and medium utilities of any group and thus more likely benefits from some economies of scale. Its cost recovery ratios are in the average range and capital needs are the lowest of any group, suggesting that on average the low rates are not a result of dependence on other revenue sources or delaying of key infrastructure investments, but a reflection of low costs.
- **Group E** has some of the highest rates (along with Group B), despite operating expenses in the average range. Interestingly it is made up entirely of small surface water utilities in rural areas with high cost recovery. Given that many small utilities are facing looming infrastructure investments these utilities may serve as a model for utilities that are already recovering in excess of their costs (presumably to cover debt service), and maintain manageable debt. Group E has the highest annual precipitation; the lack of additional resource constraint may keep their costs down compared to other small utilities.
- **Group F** is similar to Group E in terms of weather, operating efficiency, and debt ratio, but it consists of larger utilities in denser urban areas. Its operating expenses and rates are lower than Group E, confirming that economies of scale, as observed in the national level analysis, results in cost savings when other factors are held constant.

The geographic distribution of the groups and their relative sizes is shown in **Figure 17.** While each group has different median rates, and only somewhat overlapping ranges, almost all the groups still exhibit intragroup variability in rates. No one factor explains the variability in all groups. In Groups A, B, D, and E higher rates correlate well with higher operating expenses. In Groups C, higher cost recovery ratios result in higher rates; this trend is present in some other groups as well, but with many outlier utilities.

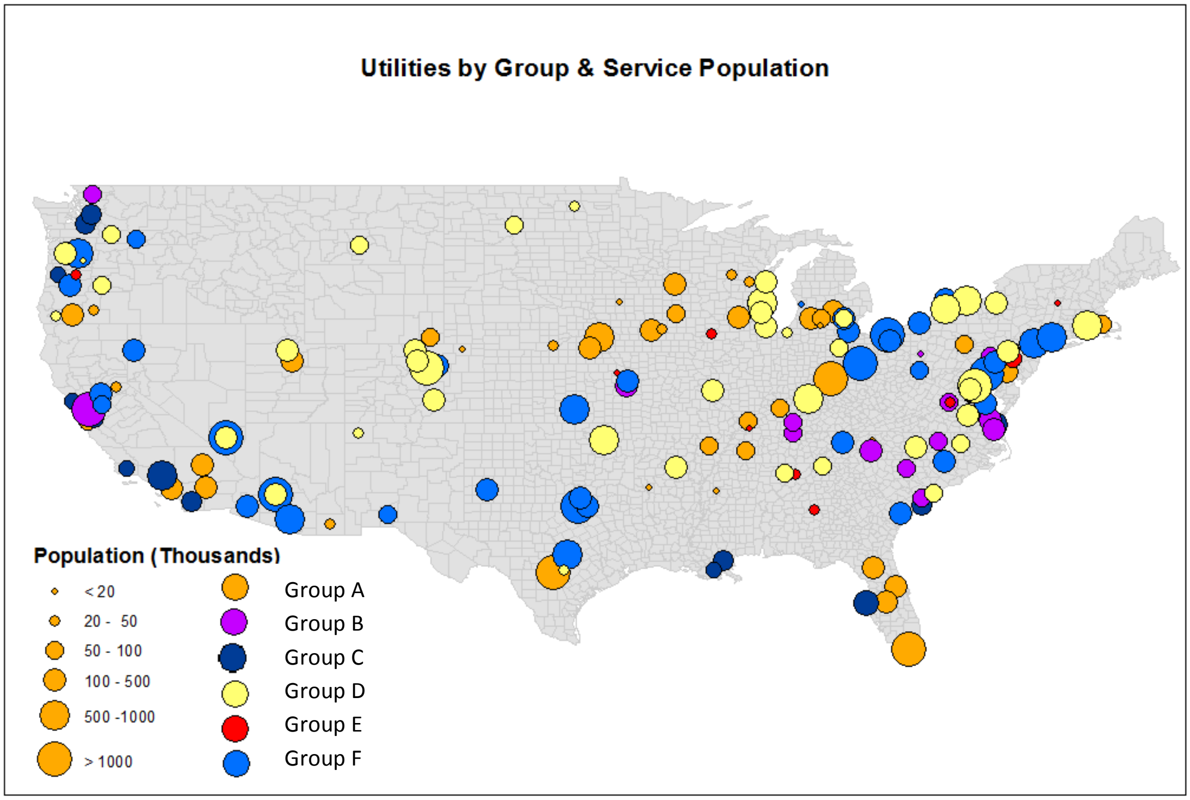


Figure 17: Utility Group Assignment and Service Population Size

The multivariate analysis provides some important insights that can be built on for further analysis. First it identifies six different utility groups, based not only on a common range of rates, but by the combined impact of the simple driving factors discussed earlier in Section II. Comparisons between the groups helps to understand national variability in rate trends, and offers the initial conclusion that costs are not the only driver of rate differences. In fact, differences in the cost recovery ratio, in combination with further understanding of current debt and potential future needs, could help begin to identify utility subsets that are at the most risk of experiencing pressing financial needs and either raising rates or decreasing quality of service as a result. Comparison across groups is informative, but comparison within groups offers useful insight about a utility's performance as well. If a utility has high operating expenses compared to its group, then this might warrant investigation into whether it is as efficient as possible. If a utility has very low rates, then it might be worth investigating whether its cost recovery ratio is similar to those in its group, and if it is lower, then why? By placing individual utilities into characteristic groups allows for more equal footing on which to compare performance and risk.

Ideally, such an analysis would be repeated with detailed operating costs, current debt, and projected future infrastructure needs.

IV. Conclusion

In Section I a brief historical analysis set the context for the paper. Both debt and rates were found to rise; in particular the top third of both rates and debt rose upward of 100% over the span of a decade, suggesting shifts in what water costs and, perhaps more importantly, how this cost is transferred to consumers.

In Section II exploratory analysis was presented to begin identifying relationships between key environmental, social and financial variables. Utility size and water source were found to be significant cost drivers. In particular, large utilities addressing a shrinking supply with source diversification exemplified a key example of the cost of water scarcity. Other findings include high variability in trends for small water utilities, particularly in terms of debt and efficiency. Furthermore, it became clear that a better indicator of how debt is transferred to the customer, debt service, would greatly improve the analysis as the available debt variables were only weakly related to water rates.

In Section III a multivariate analysis was conducted. Though it is preliminary, the utility groups identified can serve as a baseline for future analyses. If generalized, they offer simple explanations and conclusions. Groundwater utilities have lower rates because they have lower costs, but also because they have lower cost recovery (Group A). Low productivity utilities bear the additional costs of labor, passed on to the user via high rates (Group B). Increasing a utility's size, when other costs and drivers are held constant, results in a reduction of costs and rates demonstrating straightforward economies of scale (Group F compared to Group E). In reality, each group is more complex and there are always exceptions.

Future Work

The improvement of this work in the future hinges largely on more comprehensive (or more targeted) collection of utility data. The following four focus areas are recommended for future data collection and research at the national scale:

- **Debt Service Obligations:** The absence of annual debt service obligations in the AWWA survey, in addition to the long-term debt total and interest obligations, made it difficult to assess the true cost recovery efficacy of rates. In this analysis we showed that some utilities failed to cover operational costs and interest expenses through rates alone. If debt service is reported in addition to annual interest on the loan, then an improved cost recovery ratio would assess whether rates are adequate in recovering the long-term costs of water as well as the short-term.
- **Detailed O&M Costs:** A detailed cost breakdown, in particular reporting of energy and labor costs, will add robustness to some of the preliminary conclusions proposed here.

For example, it may help distinguish between utilities that are truly inefficient from those which depend on production and delivery processes that are simply more expensive. Furthermore it can help make further distinctions across regions, water source, and utility sizes that in this analysis we can make only in terms of general operating expenses.

- **Future Infrastructure Needs:** While some utilities in the AWWA survey reported projected annual average investments needs for the next five years, the value varied widely and is quite insufficient. It most likely reflects what the utility plans to invest, rather than what it should be investing based on the current state of its infrastructure. Quantifying infrastructure needs could be accomplished by surveying utilities for total length of pipes, average age of pipes and other infrastructure, number of main breaks, and other selected indicators of utility health.
- **Wastewater:** To allow for ease of comparison across utilities, this analysis focused exclusively on the production and supply of water. However, wastewater services are equally important to understand and assess on a nationwide basis, particularly because many water authorities also serve as wastewater authorities. For cash-strapped municipalities it may be particularly important to compare future infrastructure needs in wastewater compared to water, in terms of urgency and cost. Exploring whether the size and source trends identified for water utilities are similar or differ for wastewater services is potentially informative as well.

Appendix A: AWWA Variable Definitions

Primary Water Source: The source used for >60% of water supply. Split source indicates that no one source (groundwater, surface water, or purchased) is used. Purchased/other (i.e. desalination, etc…) is reported as source for some utilities and considered a fourth category.

Rate Structure: Possible rate structures include increasing block (rising cost per unit volume as more total water is used), decreasing block (decreasing cost per unit volume as more total water is used), uniform (constant cost per unit volume), and a fourth category of other which includes flat structures (one charge regardless of use).

Size: Three size groups are assigned by AWWA based on MGD. Small utilities produce less than 20MGD, medium utilities from 20 to 75 MGD, and large utilities greater than 75 MGD.

Annual Water Sold: Total water sold in Million Gallons.

Long-term debt:* All debt commitments that extend past a 12-month period

Total Assets:* Current assets, restricted assets, and any facility/equipment/property assets combined.

Total Current Liabilities: All debt due within a 12-month period.

Debt Ratio: Not a direct AWWA variable, but computed as Total Liabilities/Assets, where total liabilities are the sum of long-term debt and current liabilities.

Capital Needs:* Self-reported average annual capital needs over the next five years.

Appendix B: Climate Variable Definitions

Climate variables are all derived from NOAA county-level climate data.

Annual precipitation: The average annual sum of precipitation from 1949-2009 within the primary county served by a utility.

Seasonal precipitation: A ratio of the three highest months of precipitation (monthly averages from 1949-2009) to the three lowest months of precipitation.

Average temperature: The average daily temperature from 1949-2009.

Temperature Variability: The difference between the highest and lowest month temperature.

Appendix C: Additional Plots

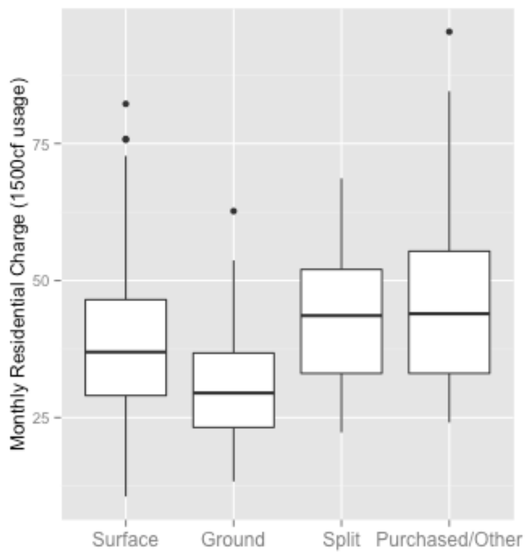


Figure C1: Monthly Residential Charge (1500 cf) by Primary Source

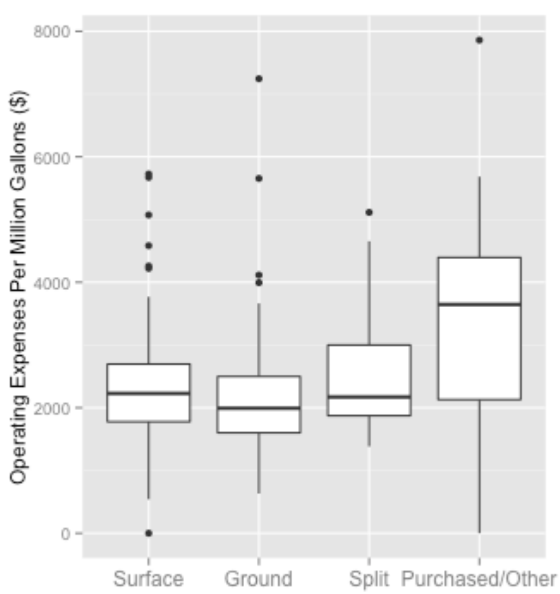


Figure C2: Operating Expenses by Primary Source

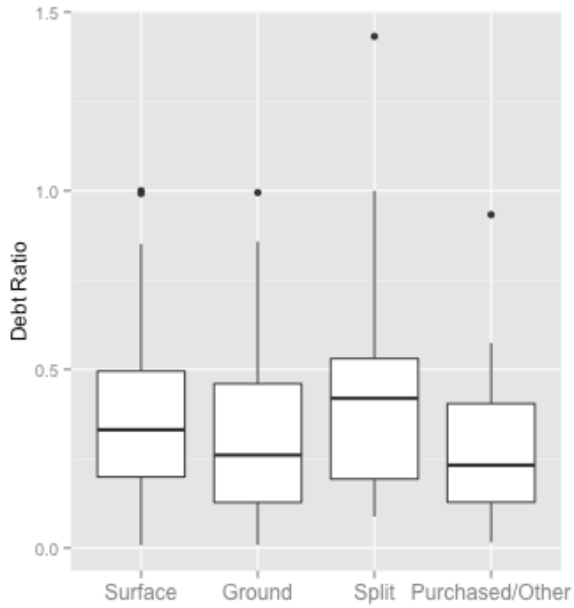


Figure C3: Debt Ratio by Primary Source

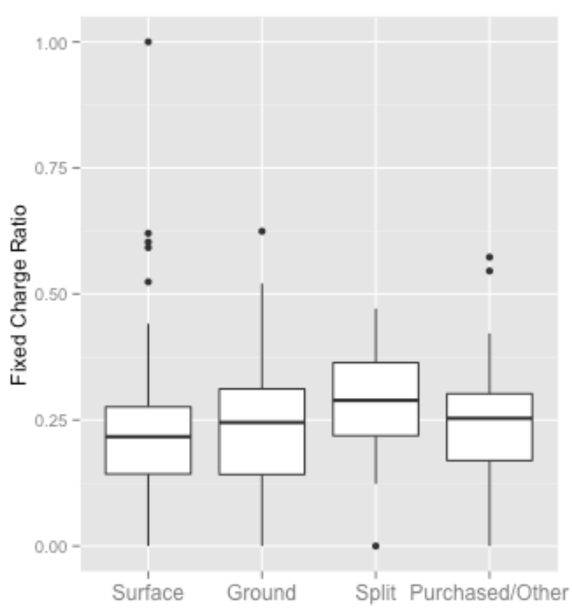


Figure C4: Fixed Charge Ratio by Primary Source

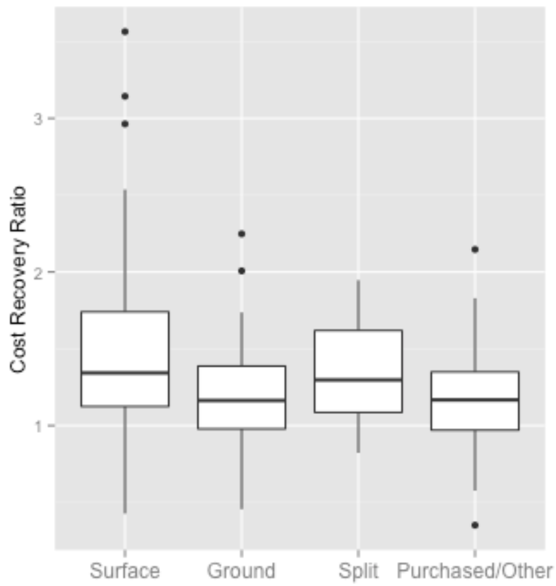


Figure C5: Cost Recovery Ratio by Primary Source

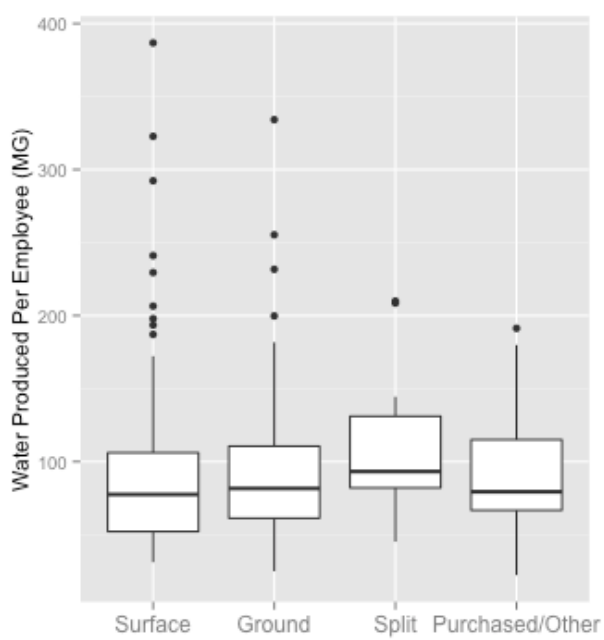


Figure C6: Water Per Employee by Primary Source

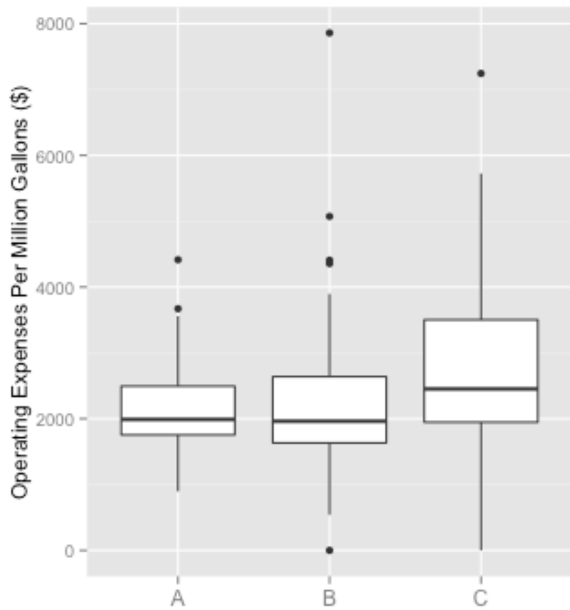


Figure C7: Operating Expenses per MG by Size

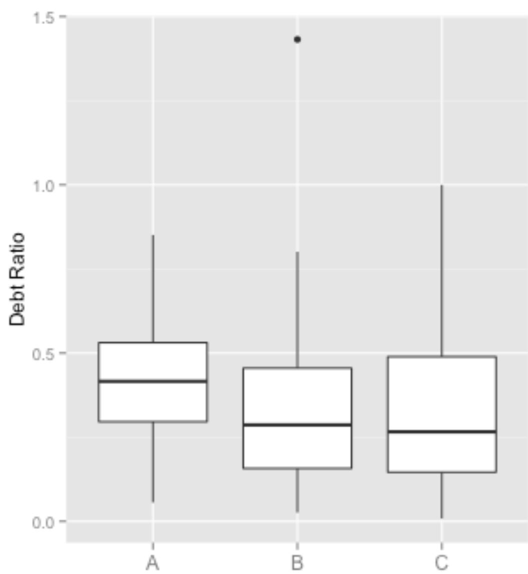


Figure C8: Debt Ratio by Size

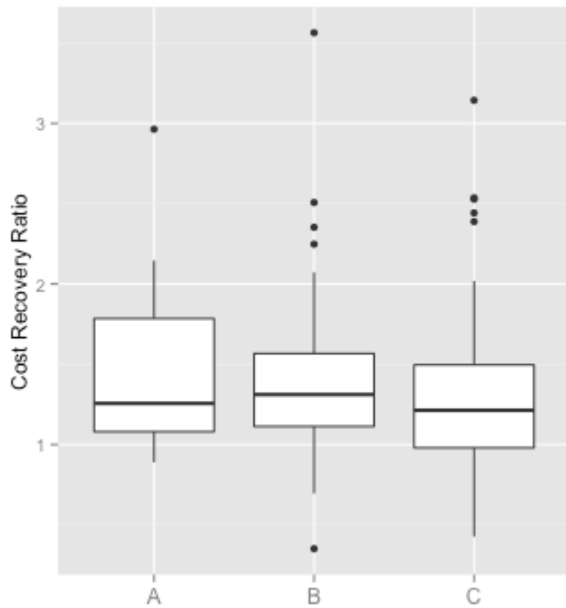


Figure C9: Cost Recovery Ratio by Size

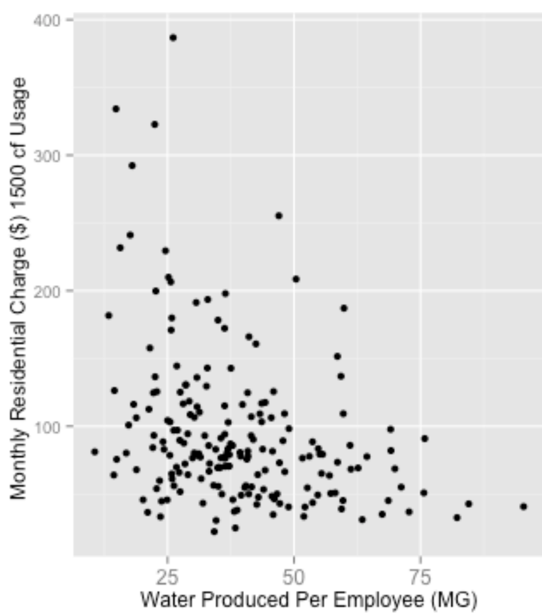


Figure C10: Residential Rate 1500cf Usage vs. Water Per Employee

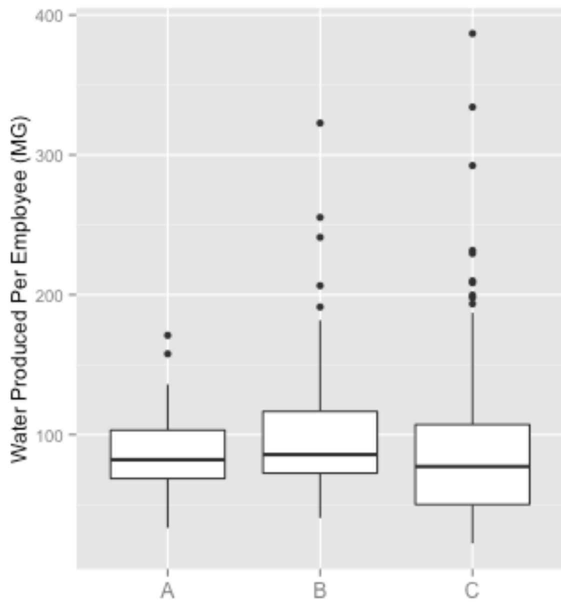


Figure C11: Water Per Employee by Utility Size

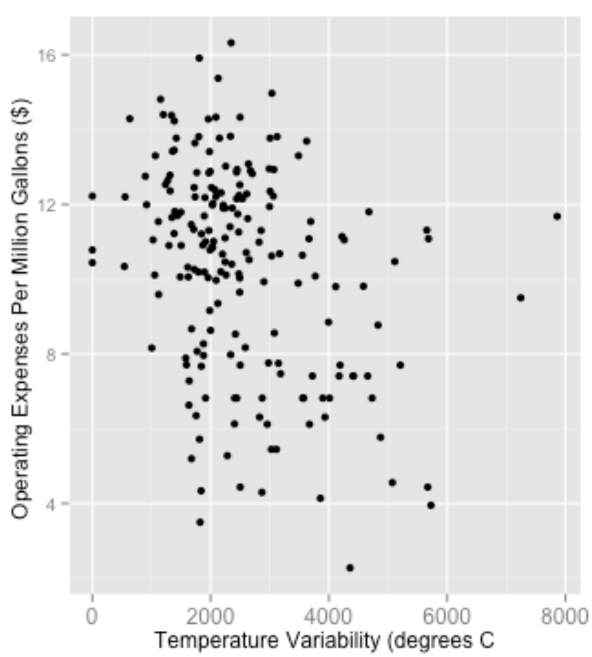


Figure C12: Operating Expenses per MG vs. Temperature Variability

Appendix D: Clustering Methodology

The clustering method applied is known as the model-based recursive partitioning and was applied using the ‘party’ package in R. The following steps summarize the algorithm:

1. Determine a model equation with response variable Y, independent variables X, and partitioning variables Z, as shown below:

   $$Y_1 = X_1 + \ldots + X_i \mid Z_1 + \ldots. + Z_j$$

   For i independent variables and j portioning variables. Since the purposes
   In
   Y_1 = Monthly Charge for 1500 cf Use

   X_1 = Debt Per Million Gallons of Water Sold
   X_2 = Operating Expenses Per Million Gallons of Water Sold

   Z_1 = Water Sold Per Employee
   Z_2 = Primary Source (1=Surface, 2=Ground, 3=Split, 4=Purchased)
   Z_3 = Median Income
   Z_4 = Service Population Total
   Z_5 = Average Day Water Production
   Z_6 = Capital Needs Per MG
   Z_7 = Annual Precipitation
   Z_8 = Seasonal Precipitation Ratio (3 highest months/3 lowest months)
   Z_9 = Average Temperature
   Z_{10} = Median Income
   Z_{11} = Population Density

2. The model $Y_1 \sim X_1 + X_2$ is fitted to all the observations.
3. Compute the stability of model parameters with respect to all the partitioning variables $Z_{1:9}$. For continuous variables, parameter instability is measured using an sup-LM statistic and for categorical variables using a chi-squared statistics for each level of the variable. In both instances the instability is associated with a p significance level value.
4. If one or more partitioning variables have p-statistics below a pre-determined threshold (0.1 was used in our model) the data is split on the partitioning variable associated with the highest parameter instability (the lowest p-value). The exact value (or level for a categorical variable) of the split is determined by minimizing the OLS function.
5. Steps 2-4 are repeated for the child nodes until 1) no splitting variables with sufficient instability or the minimum node size (set to 10 in this model) is reached.

For in-depth explanation and further examples of this method see *Party with the mob: Model-Based Recursive Partitioning,* cited in the reference section.

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