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Multifaceted intra-city water system arrangements in California: Influences and implications for residents

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ABSTRACT

Some cities directly provide drinking water and other utility services to their residents, whereas others contract out these responsibilities in full or in part, with considerable implications for service and non-service outcomes. There is a robust literature considering reasons for city-private provider binaries, as well as a growing number of studies assessing the rise in special district service provision, mixed service delivery arrangements, and inter-municipal service delivery within metropolitan contexts. On the other hand, there are few studies assessing city-level prevalence of these three main provider types jointly, as well as fully accounting for the diversity of institutional arrangements in drinking water service within individual cities.

In this study, we construct an empirical profile of and analyze influences on diverse city-level water service provider arrangements using a dataset compiled for all 482 cities in California. Our analysis shows that 80% of cities are served by either a municipality, a private, investor-owned utility or a special district, with special districts being more common than private providers. Moreover, 20% of cities had more than one service provider, and 68% of these cities were served by more than one system type, including many where municipal and private providers co-existed. Using multivariate regression techniques, we analyze influences on different types of city-level drinking water service arrangements. We find that city incorporation date most profoundly influences the mix of water systems in cities, especially arrangements involving special districts or multiple system types. We also find that cities which run their own water system exclusively are more likely to institute conservation policies, and provide suggestive evidence that residents living in cities served by multiple water systems are exposed to wide variance in water rates. Water system fragmentation within city boundaries thus has implications for resource management policy and equity in intra-city resident essential service outcomes.

1. Introduction

Cities are expected to either directly or indirectly provide basic utility services to their residents. Previous research shows that the type of provider serving a city has considerable, albeit mixed implications for residents' experience of service and non-service outcomes, as shown in the literature on urban water service provision (Bel et al., 2010; Konisky and Teodoro 2015; Lyon et al., 2017; Teodoro and Zhang, 2019; Dobbin et al., 2019; Homsy and Warner, 2020; Dawkins, 2020). Scholars have also long studied the factors influencing direct city provision versus contracting out to alternative providers of such services, especially private providers, and the in-between spaces of corporatization of service provision with and without commercialization (Warner and Hebdon, 2001; McDonald, 2016).

A robust existing literature has also analyzed the factors leading to privatization or contracting of municipal city services in urban areas in higher-income countries (see Warner and Hebdon 2001; Hefetz and Warner 2004; Bel and Fageda 2008; Bel and Fageda 2009; Picazo-Tadeo et al., 2012; Gradus et al., 2014), as well as in lower-income countries (for instance, see Pierce, 2015). Many of these studies find conflicting results in influences on utility provider type, particularly regarding the role of ideological and political factors, across a range of geographic locations and city service types. A separate strand of literature details how rapid urban growth, particularly in California and Texas, helps to explain patterns of urban service provision by other quasi-public service providers such as special districts (Burby et al., 1988; Moldogaziev et al.,

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2019). Yet few studies beyond those analyzing the phenomena of mixed public-private delivery (Bel et al., 2014) and inter-municipal service delivery (Warner, 2011)—concepts which we discuss the applicability of further below—combine a joint understanding of privatization and special district provider entry into water service delivery arrangements at the city-level. Our study also includes an expanded range of other service delivery providers operating within cities to include boutique types such as mutual water systems, which are private but not for profit, and common in contexts such as California.

In comparison to both energy and wastewater utilities, a wide range of governance types and authorities for drinking water service operate in California (Pierce et al., 2020), a phenomena which is generally prevalent across the U.S. In this study, we modify a classification of drinking water system-governance categories used in our recent work analyzing Community Water Systems (CWS) (Pierce and Gmoser-Daskalakis, 2020) and draw on the typological classification of California water system types by Dobbin et al. (2019). This enables us to illustrate and explain both the dominance of public, private, and special district provider types in water service delivery in a standalone fashion to individual cities, as well as the proliferation of multifaceted system arrangements within a minority of cities. Unlike previous studies, our work explicitly examines the full range of what we call drinking water system governance arrangements at the city level across all 482 incorporated cities across California. We then use descriptive statistics and regression models to examine the factors that affect the types and number of major water systems found in individual cities. Sixty percent of cities fit the public-private binary and 80% the public-private-special district conception, but nearly 20% had more than one service provider. Among the 103 cities with more than one sizable system, 68% were also served by more than one system type and thus roughly corresponds to a 'mixed service delivery' arrangement which involves both governments and private partners providing water service to residents within a single city (Brown et al., 2016; Bel et al., 2014).

Using multivariate regression, we begin to explain additional complexity in the presence and type of arrangements of drinking water service providers serving individual cities. Unsurprisingly, cities which directly operate other utility services are more likely to operate their own water system. We find that incorporation date most profoundly influences the form of water system arrangements in cities. This suggests the importance of historical growth and city governance decisions in defining current utility provision arrangements. We also find that cities which run their own water system exclusively are more likely to institute conservation policies, and suggestive evidence that residents living in cities served by multiple water systems are exposed to wide variance in water affordability. Our findings also suggest the many water system arrangement types at the city-level present unique challenges for governance, and which problematize simple notions of the extent to which city services are "privatized" and that intra-city resident access to utility services is consistent. Moreover, the extent and consequences of intra-city water system fragmentation underscore a policy emphasis on and potential for consolidation efforts by city governments, including in cities served by private providers, which may improve service and non-service outcomes for residents.

2. City-level water system types and arrangements

Given the necessity of water for dense development, the relationship between drinking water systems and urban local bodies—in the California context, cities—plays an important role in urban land development and planning patterns, growth control, and land annexation patterns (Mukhija and Mason, 2013). Once incorporated, cities can use their police powers for control over the process of utility service extension to control growth (Biggs 1990). This control, however, does not usually apply to service provider arrangements put in place before incorporation, or necessarily to arrangements the city has agreed to post-incorporation, particularly in cases of private involvement in urban water provision (Mann and Warner, 2019). There is often, if not always, a power asymmetry between the local state and private providers which reflects the persistence of the neo-liberal paradigm even in contexts where it is actively contested (Swyngedouw, 2005; Bakker, 2013). This study connects existing strands of literature on city-level utility service privatization and corporatization (especially for water), the role of special districts in water service provision and related scholarship on mixed and inter-municipal service delivery, and the causes and consequences of water system fragmentation.

A robust existing literature studies the factors leading to privatization or contracting of municipal city services in higher-income countries (see Warner and Hebdon 2001; Hefetz and Warner 2004; Bel and Fageda 2008; Bel and Fageda 2009; Picazo-Tadeo et al., 2012; Gradus et al., 2014), as well as in the developing world (for instance, see Pierce, 2015). Many of these studies focus on drinking water service, and find conflicting results in terms of driving factors, particularly ideological and political factors, across a range of geographic locations and city service types. As Bel and Fageda (2009) note, there is no clear consensus as the findings of each study are sensitive to the context.

While privately-run systems are often seen as the dichotomous, outsourced alternative to city-run systems, both hybrid intra- or inter-city service arrangements have been identified, sometimes with overlap (Gradus et al., 2014) and have relevance for this study. In terms of intra-city service arrangements, the term mixed service delivery describes where local governments mix delivery by using both private contracts and public production for the same service (Bel et al., 2014). Trends over the last two decades in municipal service provision indicate restructuring, including more mixed or hybrid forms of public-private delivery, is increasingly common. These studies, however, tend to assume more agency if not strategic control by city governments in mixing service providers than is found in the California context (Hefetz, Warner and Vigoda-Gadot, 2014).

The growing trend of inter-municipal service delivery, in which one government agency jointly provides utility services to proximate residents outside its technical jurisdiction, across otherwise discrete city or county boundaries, also has relevance to this study. Hefetz and Warner (2004) found in a survey of 628 U.S. municipal governments that about three quarters both contracted out new services and contracted back in others (i.e. local government brought service provision back in-house). Both Levin and Tadelis (2010) and Homsy and Warner (2014) also find evidence of inter-municipal cooperation, with the latter finding that this phenomenon grew in occurrence from 17% to 24% of U.S. local governments between 2002 and 2012. When comparing internationally, Warner and Bel (2008) found privatization more common in Spain than the U.S., largely due to the higher prevalence of hybrid public-private firms in Spain. Bel et al. (2018) acknowledges more recently that mixed delivery options have grown alongside private contracting for municipalities over time, while Gradus et al. (2014) also finds evidence of both mixed service delivery and inter-municipal cooperation in trash collection in the Netherlands.

Both the concepts of intra and inter-city service delivery models also relate to the rise of special districts in the western U.S. For instance, Jossart-Marcelli and Musso (2005) expanded the definition of outsourcing of city service provider types to address the role of special districts, while also documenting that city services can be outsourced to other governments, such as other cities, county governments, or special districts. More broadly, rapid urban growth, particularly in the Western U.S., can explain a greater share of urban service provision, especially drinking water, by entities such as special districts (Mullin, 2009). Special districts—local government entities created and funded by local residents to provide a specific service such as drinking water—are more common in unincorporated than incorporated areas, but have been deployed as an alternative to city-run management for financing and providing utility service in fast growth states like California. Scholarship dating back to early work by Vincent Ostrom (1962) documents how growth in Southern California was driven by how special districts controlled and allocated scarce water supplies. Burby et al. (1988), however, find that special districts fail to facilitate the kind of coordination between water/sewer extension and land use planning that is possible when all services are housed within city government. Support for closer examination of special districts for water governance comes from their commonality in other states, especially in Texas (Moldogaziev et al., 2019). Goodman (2020) finds a link between smaller central cities, special district overlap, and population growth while Nunn and Schoedel (1997) note a pattern of relatively high reliance on special districts for service provision in Western U.S. metropolitan areas. The U. S. Census tracks special districts and has found water special districts continue to grow across the country; California, Arkansas, Missouri, and Washington states each added 10–20 water supply districts from 2010 to 2017. As of 2017, 3593 single function water supply special districts existed across the U.S. along with 1380 multi-function water supply and sewerage districts and 140 multi-function natural resources and water supply districts (America Counts 2019). Ostrom (1962) traced the rise of special districts in California back to the 1887 Wright Act which enabled municipal corporations to be organized in communities for water supplies.

In comparison, Mutual Water Companies (MWCs) and their functional equivalents do exist in states outside of California but are less common than special districts. MWCs are largely found in California and Utah (Bagley and Haws 1985; Ostrom 1962) and similar small water supply corporations are found in Texas (Jepson and Brown, 2014). MWCs were historically formed as mutual irrigation companies in some portions of Colorado, Montana, Idaho, Wyoming, Oregon, and New Mexico, suggesting they are a unique product of historical development in the West (Hutchins 1936).

There is robust scholarship on drivers of diversity in city-level water system arrangements with applicability to our study. Accordingly, we include Table A-1 in the Appendix which summarizes the findings from studies analyzing city-level water and utility provider type regarding major explanatory factors. Several studies find pragmatic reasons are more important than ideology and politics in driving service provision choices (Bel and Fageda 2008 (for small cities); Bel and Warner 2008; Warner and Hebdon 2001) while other studies suggest political and ideological factors matter to some degree (Bel and Fageda 2009; Gradus et al., 2014; Bel and Fageda 2008 (for large cities); Picazo-Tadeo et al., 2012). Joassart-Marcelli and Musso (2005) find that city institutional characteristics and fiscal stress play major roles in explaining service provision arrangements in Southern California. While poorer cities outsourced more services than wealthier cities, poorer cities tended to outsource service delivery to government agencies while wealthier cities tended to privatize services when outsourcing (Joassart-Marcelli and Musso 2005). The authors also find more outsourcing in younger, smaller, suburban cities and general law, city-manager cities with more conservative voters.

Each of the studies referenced above has great value given the prevalence of public, private, and special district drinking water systems serving cities. Many of these studies also allow for more causal analysis of reasons for transitions in city-level arrangements, as well as further identification and testing of specific political and managerial factors than is possible in our analysis. We utilized as many factors shown to be significant from these studies in our own regressions as our cross-sectional dataset would allow. However, previous studies often assume that a given service will be provided by a single service provider within a city's jurisdiction, or simplify the diversity of providers to binary, mixed or hybrid classifications. On the other hand, we find that water is unique in terms of the potential for multifaceted arrangements providers and provider types operating in a single jurisdiction. Our research proposes and explains both the dominance of the public, private, and special district models of urban water service delivery, as well as the proliferation of other arrangement types at the city-level which present both unique challenges for governance, notions of the extent to which city services are public versus privatized, as well as assumptions regarding equity in intra-city resident service outcomes.

3. Data and methods

To identify and analyze variation in city-level water system arrangements, we manually constructed a dataset of the utility service providers and other socioeconomic and governance characteristics of all 482 incorporated cities in California as of 2020. We used two primary methods to identify the type and number of water system serving each city: website scraping and GIS matching of system and city boundaries. Information was initially collected from city websites and coded using the governance classification categories explained in our previous study (Pierce and Gmoser-Daskalakis, 2020). When this information was unavailable on official city websites, service providers were identified from other publicly available municipal planning documents (including general plans, environmental impact reports, urban water management plans) and failing that, from news stories and non-city websites.

As an additional check on which and how many water systems served each city in California, we used spatial matching that joined relevant[1] community water system boundaries to city boundaries in ArcGIS 10.7 using publicly-available shapefiles. After extensive manual cleaning to exclude unintended, small overlaps in boundaries and erroneous entries, this exercise identified 15 additional systems with over 1500 connections for inclusion in our dataset of service providers, and 100 additional systems under this size threshold. This increased our estimate of cities with 2 or more sizable water systems operating within their boundaries from 90 to 103. In this analysis, we exclude small systems (fewer than 1500 connections) because the focus of this study was a classification of major service arrangements for city populations. This exclusion was further validated by the lack of explicit recognition by cities of smaller systems in their service arrangements: none of these systems were found on city-websites informing residents of relevant service providers. We analyze these systems in a separate forthcoming analysis focused on intra-city consolidation potential, and also note that their inclusion in this analysis does not substantively change the regression model findings reported in the current study.

Following these two data collection exercises, we coded drinking water systems into five major governance types: city-run, investor-owned utility, mutual water company, special district, other governance type. We then condensed 21 unique system arrangement combinations (shown in Appendix table A-2) into four major city arrangement types for the purpose of further analysis: only city-served, only IOU-served, only special district-served, or another arrangement.[2] The vast majority of other arrangements reflected a mix of system governance-types.

To help explain variation in city-level arrangement size and type, based on our literature review, datapoints in the following categories of independent variables were collected and considered for inclusion in multivariate analysis: city structure, political trends, municipal finances and corporatization structure, and growth trends, shown in further detail below.

- City Structure
  - o Government structure (e.g. council-manager, mayor-council, commission)
  - o Founding law (charter, general)
- Political Trends

[1] Although some prisons, camps and schools are classified as community water systems, we excluded such systems and any other system serving institutional or residential populations which are not typical "customers".

[2] These categories were created to identify the cities with one of the main provider types (city-run, IOU, special district) as typically examined in the existing literature. Cities with more than one water system of different types (one of the three plus mutual water companies) were grouped in the other category as they did not meet the 'single service provider' assumption.

- o Percent democratic votes in 2016 presidential election
- Municipal Finances
  - o Municipal financial risk designation
  - o Number of city enterprise funds
- Growth Trends
  - o City incorporation date
  - o Number of annexations and total acreage annexed 1980–2019 (from Census Boundary Annexation Survey)[3]

We also collected U.S. Census data on population (total number and by racial-ethnic category), and median household income to account for the population, population density, racial-ethnic and income makeup of each city. We created dummy variables for location in the state's six metropolitan statistical areas (MSA) to control for regional trends, but separated out Los Angeles County from the Los Angeles-Orange-Ventura counties MSA, given its unique size and political culture in California.

As a final component of the analysis, we used data we had previously collected on water system conservation policies and residential rate levels to provide suggestive evidence regarding the consequences of different system arrangements. At the state level, water system conservation policy data were derived from the California Governor's Office of Planning and Research (2018) Annual Planning Survey (APS), which surveyed California cities regarding how many and what kind of water use efficiency programs or policies were enacted by the city. Additionally, residential rate data was calculated based on rate sheets collected during a previous study by the authors for all 88 cities in Los Angeles County.

3.1. Methods

We first utilize this composite dataset to describe the landscape of 1) whether a city operates its own water system and 2) the types of system arrangements that serve cities across the state. We then build multivariate regression models to further analyze two outcomes of interest: 1) the presence of a city-run water system (binary), 2) the city-level system arrangement type (multinomial logit). Our employment of independent and control factors in the final regression analysis was narrowed based on data quality, variation of characteristics across cities,[4] and parsimony to the following variables: incorporation year, population, percent non-white population, median household income, percent democratic votes in 2016 presidential election, financial risk designation, and regional locations (based on five major MSAs and Los Angeles County). All variable coding, descriptive and multivariate regression analyses were performed in Stata Version 15.1. We also explore performance implications of different water service provider arrangements. We examine adoption of water use efficiency polices by cities across the state using 2018 APS data. We then examine average water bills in cities with the highest number of systems in Los Angeles County (5 or more systems) to assess potential affordability implications of urban water system fragmentation.

[3] The annexation data was originally included given the potential for cities to annex land already served by an existing water system, which may lead to maintaining that water system and thus multiple systems. Ultimately, however these were excluded from the regression models given that the Boundary Annexation Survey from the Census only provides public data from 1980 onward, and involves different city-reported units of data, so it was difficult to verify the validity of this data and failed to cover enough history of city annexations.

[4] As Table A-3 shows, aggregate data do not allow for a deep analysis of the extent to which California cities vary with respect to degrees of corporatization and commercialization of water systems or other utility services. Accordingly, although these characteristics were of interest based on previous studies, they were not further analyzed (for instance, Voorn et al., 2020).

4. Results

In this study, we focus on the diversity of system arrangements within incorporated city boundaries. Table 1 illustrates that cities are served by only 635 of the 2879 community drinking water systems in California, whereas they house 84% of the state's population. Systems serving cities are nearly twenty-times larger on average than systems serving unincorporated areas, suggesting the potential for disparate service outcomes and motivation for consolidation outside cities. Some single-city systems serve very large populations, including the Los Angeles Department of Water and Power serving about 10% of the state's population alone, and some IOU and special district systems span multiple cities. In short, there is not nearly as much water system fragmentation in cities as compared to unincorporated areas (Pierce et al., 2019).

Of the 482 incorporated cities in California, the vast majority (79%, 379 cities) have a single water system provider. However, at least 103 cities are served by multiple large systems. About 57% of cities (275) operate their own water system, of which 86% (237) are the sole provider of water service to the city's residents. However, among the 103 cities with more than one water service provider, the majority feature a mix of governance types (see Fig. 1). For the 31 cities with multiple systems of the same type, the vast majority (23 cities) were served by an arrangement of multiple special districts, whereas only 20% of cities had multiple IOU providers.[5] Notably, 53% of cities with 2+ system types (38 cities) featured a city-operated system serving residents alongside other system types, highlighting that city service provision is not an all or nothing proposition. Although the sample size is small, it also appears that cities with multiple system arrangements are roughly equally likely to operate their own water system alongside an IOU as they are alongside another public or quasi-public system type. See Appendix Table A-2 for a categorization of each unique system arrangement type among cities served by multiple water systems.

4.1. City-level arrangement characteristics

We next examine the relationship between city-level water system arrangement type and other city characteristics, with a focus on governance attributes. Appendix Table A-3 illustrates differences in characteristics between cities that run their own water system and those that do not. Incorporation date is found to be significantly correlated with the presence of a city-run water system. Younger cities are also more likely to have more water systems while older cities are more likely to have city-run systems. City location in Los Angeles County was significantly positively correlated with having a higher numbers of water systems, whereas location in three of the five MSAs (San Diego,

Table 1
Estimates of water system prevalence and size by city-status in California.

	Number of major CWS Systems	Total Population 2018	Average Population per System
State of California	2879	39.46 million	13,706
482 Incorporated Cities	635	32.99 million	51,953
Unincorporated Areas	2244	6.47 million	2883

Note: Unincorporated area totals derived by subtracting values of city totals from statewide totals.

[5] Two unique city arrangements were found in Los Angeles County. One city (Maywood) was served by three separate mutual water companies. Another city (West Hollywood) is the only city in turn served by two other cities (City of Los Angeles and City of Beverly Hills systems).

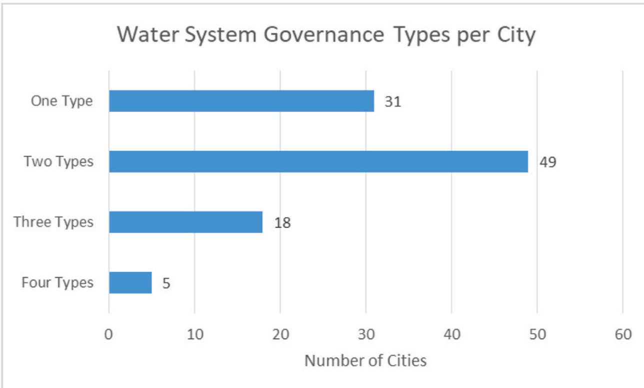

Fig. 1. Number of governance types in cities with multiple water systems (n = 103).

San Francisco-Bay Area, and Riverside-San Bernardino) were negatively correlated with likelihood of a city-run system. This suggests some regional differences in patterns of city-level water system arrangements and fragmentation. In terms of other city-level factors, the proportion of Nonwhite population was significantly positively correlated with presence of a city-run water system while a council-manager structure was negatively correlated. The proportion of Nonwhite population in a city was also significantly positively correlated with the number of systems serving its residents. Higher household median income was significantly negatively correlated with cities operating their own water system.

4.2. Multivariate regression model results: city-run systems and city-level arrangements

We then use multivariate regression techniques to model two outcomes of interest in cities across California: 1)the presence of a city-run water system (binary), 2) the city-level system arrangement type (multinomial logit). Our final regression analyses excludes some independent variables and control variables initially considered given a combination of multicollinearity, poor data quality (e.g. annexation data was only available from the US Census post-1980) and low outcome variability (96% of all California cities have a council-manager structure) concerns. For both models, we present variable coefficients and their levels of statistical significance in relationship to the outcome of interest, standard errors, as well as overall model fit results.

Table 2 shows the results from our binary logistic model. Cities are more likely to operate their own water system if they are older, have a higher population and proportion of Nonwhite residents, and have lower levels of financial risk. With the exception of the Sacramento MSA, cities in all other metros studied are significantly less likely to run their own water systems. On the other hand, household income and political affiliation were not found to be significantly correlated with city self-provision of water service in the regression model, despite a significant negative relationship found between income and city-run service in bivariate correlations.

Table 3 shows that there are both similar and disparate trends in comparison to the binary city-run model when modeling a more diverse set of arrangement types. Larger population of cities is significantly positively correlated with city-run and other types of system arrangements compared to the base category of IOU-run systems. Younger cities are more likely to be served by special district or more boutique service arrangements than older cities. Cities in Los Angeles County are significantly less likely to have city-run systems, cities in Riverside-San Bernardino and San Francisco Bay Area MSAs are more likely to be served by special districts, and San Francisco Bay Area MSA cities are more likely to have other system arrangements while the opposite is true for cities in the San Diego MSA. As in the binary regression model, several

Table 2
Binary Logistic Model of City Operating its own Water Systems (n = 476).

Variable	Coefficient (robust std. error)
Incorporation Date	**−0.027 (0.004)*****
Log of 2018 Population (in 1000s)	**0.215 (0.106)***
Nonwhite (Percentage)	**0.016 (0.006)****
Median Household Income (in 1000s)	−0.002 (0.005)
Percent Democrat Voters 2016	−0.002 (0.008)
City Financial Risk Level	**−0.638 (0.215)****
LA County	**−1.418 (0.365)*****
Orange County/Ventura MSAs	**−0.953 (0.434)***
Riverside/San Bernardino MSAs	**−1.693 (0.447)*****
Bay Area MSA	**−2.222 (0.508)*****
San Diego MSA	**−2.745 (0.801)****
Sacramento MSA	−1.113 (0.582)
Constant	**54.191 (7.324)*****
Model Fit- Wald chi^2 (12)	94.08
Model Fit- Prob > chi^2	0.0000
Model Fit- Psuedo R^2	0.2703
Model Fit- Mean VIF	8.71
Model Fit- Hosmer-Lemeshow chi^2 (8)	6.34 (p = .6086) (not significant)
Model Fit- Link Test	hatsq p value = .337 (not significant)

p < .05 (*), p < .01 (**), p < .000 (***).

Table 3
Multinomial logistic model of city water system type (n = 475).

Variable	Coefficient (robust std. error)
City Run System	
Incorporation Date	−0.007 (0.005)
Log of 2018 Population (in 1000s)	**0.339 (0.158)***
Percent Nonwhite	−0.0035 (0.008)
Median HH Income (in 1000s)	**−0.012 (0.006)***
Percent Democratic Voters in 2016	−0.010 (0.010)
Financial Risk Level	−0.358 (0.315)
LA County	**−1.555 (0.494)****
OC/Ventura MSAs	−0.764 (0.733)
Riverside/San Bernardino MSAs	0.026 (1.116)
Bay Area MSAs	−0.722 (0.710)
San Diego MSA	−1.911 (0.995)
Sacramento MSA	−0.058 (1.046)
Constant	16.548 (9.460)
IOU (base outcome)	
Special District	
Incorporation Date	**0.026 (0.006)*****
Log of 2018 Population (in 1000s)	0.320 (0.180)
Percent Nonwhite	**−0.030 (0.010)****
Median HH Income (in 1000s)	**−0.018 (0.007)***
Percent Democratic Voters in 2016	−0.012 (0.013)
Financial Risk Level	0.172 (0.356)
LA County	−0.527 (0.584)
OC/Ventura MSAs	0.258 (0.817)
Riverside/San Bernardino MSAs	**2.323 (1.143)***
Bay Area MSAs	**2.643 (0.790)****
San Diego MSA	1.152 (0.960)
Sacramento MSA	0.505 (1.209)
Constant	**−48.827 (11.695)*****
Other (multiple system types, other city extends service, mutual)	
Incorporation Date	**0.0121 (0.006)***
Log of 2018 Population (in 1000s)	**0.514 (0.197)****
Percent Nonwhite	0.006 (0.011)
Median HH Income (in 1000s)	−0.010 (0.009)
Percent Democratic Voters in 2016	−0.015 (0.13)
Financial Risk Level	−0.134 (0.360)
LA County	0.258 (0.623)
OC/Ventura MSAs	0.203 (0.881)
Riverside/San Bernardino MSAs	1.821 (1.184)
Bay Area MSAs	**1.714 (0.825)***
San Diego MSA	**−13.149 (0.934)*****
Sacramento MSA	1.142 (1.171)
Constant	**−23.670 (11.671)***
Model Fit- Wald Chi^2 (36)	2251.44
Model Fit- Prob > Chi^2	0.0000
Model Fit- Psuedo R^2	0.2313

p < .05 (*), p < .01 (**), p < .000 (***).

factors significant in bivariate correlations lost significance in the multinomial logistic model, including financial risk level across all arrangement categories.

Both regression models exhibit basic goodness of fit and moderate explanatory power. The binary city-run model did not appear to suggest omitted variable bias based on the Link Test and Hosmer-Lemeshow Chi-square statistics. The mean Variable Inflation Factor (VIF) for this model, which measures collinearity concern, had a moderately high value of 8.71. This value was influenced by three variables with high (above 10) VIFs: incorporation date, percent democratic voter, and household median income. This result shows that incorporation date, the most influential variable in our models, was highly correlated with several other city characteristics. We retained the other two variables in the model, however, despite the higher VIFs as they acted as controls for political and income aspects of cities which are otherwise uncaptured in our estimates.

4.3. System performance analysis results: conservation and affordability

Fragmentation in the number and type of water service providers in jurisdictions such as cities has potential implications for system performance and the uniformity of residential access to water service. Based on available data, we explore whether fragmentation in city-level arrangements in California affected the outcomes of water conservation policy implementation, and resident experience of consistency in water rates within the same city.

Analysis of data from the 2018 Annual Planning Survey of 293 California cities revealed that the vast majority of cities (250 cities or 85%) have water systems that enact water use efficiency policies and programs. The most common programs were ordinances or landscaping standards (244 cities), LID standards (175 cities), residential water use restrictions (131 cities), and residential water metering requirements (129 cities). Of these 250 cities, most had city-run water systems (128 or 85%) with smaller numbers of cities having special districts (64), IOUs (30 cities), or other/mix of systems (34 cities). Cities with city-run systems reported implementing statistically-significantly more conservation practices with an average of 4.1 practices per city, followed by other system mixes (3.3 average practices) and special districts and IOUs (both 3.1 average practices). This may be related to the fact that cities which run their own water system have more jurisdiction to single-handedly enact all conservation policies whereas other service providers must coordinate with cities on implementating many of these practices.

The presence of multiple systems in a city can also result in disparate affordability implications for residents, with different neighborhoods being served by different systems with very different rate structures. Using water bill data from Los Angeles County water systems in 2019, we examined rates at a constant consumption level (12 CCF) in cities with the most fragmented water system arrangements—5 or more systems.

As Table 4 shows, even similar average monthly rates across cities served by many systems can mask considerable variability between customer bills within a single city. Several cities, such as West Covina, Covina, and Norwalk, see residents facing rates from the highest rate service providers which charge over twice the rate as their lowest rate provider. All of these involve IOUs with much higher rates than public or mutual systems in the same city, although this small sample would need to be expanded to determine any definitive trends. This is also not to say that higher rates are definitely inappropriate than lower ones, but the proximity of systems suggests that their cost basis should be more similar than their rates suggest. No matter the cause, the wide disparity in affordability faced by residents within the same city calls into question their equal experience of the right to the city, a concept which is premised on uniform, essential service provision by the city to meet the needs of residents (Bhan, 2009; Parnell and Pieterse, 2010).

Table 4
Intra-city water rates[6] of cities with most systems (>4) in Los Angeles County.

City Name	Number of Water Providers	Average Rate	Lowest Rate (System Type)	Highest Rate (System Type)
El Monte	8	$57.77	$42.72 (City)	$68.30 (IOU)
West Covina	8	$56.43	$33.81 (Other City-Azusa)	$83.60 (Special District)
Industry	6	$63.10	$51.00 (Special District)	$83.60 (Special District)
Bell	5	$63.15	$40.50 (Mutual)	$82.40 (IOU)
Covina	5	$54.16	$33.81 (Other City- Azusa)	$68.27 (City)
Irwindale	5	$52.10	$33.81 (Other City- Azusa)	$68.30 (IOU)
Montebello	5	$65.16	$48.63 (Mutual)	$77.21 (IOU)
Norwalk	5	$68.63	$31.43 (Other City- Cerritos)	$102.74 (IOU)
Rosemead	5	$58.68	$46.38 (Special District)	$68.30 (IOU)
San Gabriel	5	$55.84	$44.55 (Mutual)	$68.30 (IOU)
Temple City	5	$52.50	$44.55 (Mutual)	$65.13 (IOU)

5. Discussion

In our analysis of city-level water system arrangements across all incorporated areas in California, we find that a single city-run, special district or IOU water system serves the vast majority (80%) of cities. However, special districts were more than twice as likely as IOUs to serve cities, and 20% of cities were served by two or more systems simultaneously.

Building on several strands of literature, especially those on mixed service delivery arrangements and inter-municipal service delivery, we thus suggest an expansion of the traditional public or private models of city-level water system arrangements. This allows us to present evidence on the city-level prevalence of these three main provider types jointly, as well as fully detail the diversity of institutional arrangements in drinking water service within individual cities, and document some of the implications of intra-city fragmentation.

In particular, the significant proportion of cities with arrangements comprising different system governance types serving within their boundaries builds upon the phenomena of intra-city mixed service delivery which has not been as much explored in the drinking water system governance literature as compared to inter-city cooperation, much less a binary public-private framing (Bel et al., 2014; Homsy and Warner, 2014). As noted above, however, the literature on mixed service delivery largely assumes strategic control by city governments in influencing the mix of service providers (Hefetz, Warner and Vigoda-Gadot, 2014). The prevalence of multiple systems within cities in the study context, however, appears to reflect a mix of co-existence, cooperative or competitive relationships between systems depending on the city. Our findings regarding water conservation policy at the city level cohere more with previous research which has highlighted that different system governance types often struggle to work in a coordinated fashion (Burby, 1988), and in turn present a concern for comprehensive resource management among cities with mixed arrangements (for instance, see Homsy and Warner, 2020).

We found moderate levels of explanatory value in our multivariate regression models of city arrangement type, in line with most of the literature we reviewed employing similar modeling. The only

[6] Rates were obtained from 2019 rate sheets and refer to the monthly cost for 12 CCF of consumption.

consistently significant factors across both model types, however, were a city's metropolitan location and its date of incorporation. In terms of metropolitan differences, results were significant but conflicting across models, suggesting potentially unobserved regional political economy or regulatory factors influence system arrangements at the city-scale. Differential activity levels of Local Agency Formation Commissions (LAFCOs), which operate in every county in California to review city annexations and special district service extensions may explain some of this variability, and merit further exploration (Pierce et al., 2019). By comparison, the importance of incorporation date in both models shows the importance of the historical development of cities and their growth patterns in shaping the system arrangements seen today. Cities which incorporated later are more likely to have an eclectic mix of special district, multiple, and non-city run water systems serving their residents. This finding echoes that of Joassart-Marcelli and Musso (2005) regarding the importance of path-dependency in municipal service provision; cities often have trouble changing the service arrangements made at the time a city is formed, as seen. While we incorporated data on aggregate historical growth and annexation factors in some of our initial analyses, the cross-sectional nature of our research clearly limits our ability to explain cities' historical trajectories in full. Further research is needed into how historical growth, development, and annexation decisions account for the existing water system arrangements seen in incorporated cities, and whether these arrangements are preferred by cities or their residents.

Moreover, while we present an expanded classification of system governance types in this study compared to much of the literature, other studies have analyzed and shown the performance differences between an even more diverse set of water system types in California (Dobbin et al., 2019), a typology which may be worth exploring further in the purely-urban context. Our research approach could also be extended to examine whether and how the multiplicity in city-level water system type and number holds over time (ie, Gradus, 2014), and across contexts in the U.S. Finally, future studies should more fully assess the service and non-service outcome implications of the multifacted city-level water system-arrangements documented in our work Our suggestive findings using data on on state-wide conservation practices and water rates in Los Angeles County show that system governance types are associated with variation in water conservation and affordability outcomes. While differences in performance between public and private systems have been examined with mixed results, it is important to empirically examine the resource implications of household-level consequences of the more diverse set of city-system arrangements observed to understand where policy and planning intervention is most needed.

6. Conclusion

In this study, we built a unique dataset of all drinking water system providers operating in California's 482 incorporated cities. This allowed us to introduce the concept of, illustrate the extent of, and examine potential explanations for a more diverse set of city-level water system arrangements than previously documented. Building on existing studies, we suggest an expansion beyond both the traditional public or private models and the more recent expansion of attention to special districts. In terms of drivers of variation in arrangements, historical patterns of development help to explain instances of non-city provision and intra-city water system fragmentation. A major finding from our research is that incorporation date is a significant variable influencing the types and arrangements of water systems at the city-level, particularly the system types that expand beyond single public or provider types. A separate, ongoing analysis by the authors thus further examines how the factors of historical population growth, annexations, and incorporations of areas with existing water service providers helps explain patterns of multiple water providers in California. Future research should examine which historical factors and regional patterns relate to water system governance types, and how much these factors change over time. As our research shows, addressing intra-city service provider relationships which reflect co-existence or competition can also help improve equity in essential service outcomes for growing urban populations.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
Summary of Literature Review on Municipal Service Privatization Literature

Category	Factors	Research Findings
City Structure Factors	City Size (Large/Small)	Picazo-Tadeo et al., (2012), Levin and Tadelis (2010), Hefetz and Warner (2004), 2012, Gradus et al., (2014), Joassart-Marcelli and Musso (2005)
	City Type (Suburb, Rural, Metro City)	Warner and Hefetz 2002, 2003, 2012, Hebdon and Jabette 2008, Bel and Fageda (2008), Joassart-Marcelli and Musso (2005), Hefetz and Warner (2012)
	Population Density	Gradus et al., (2014), Bel and Fageda (2008)
Ideology/Political Factors	Interest Groups	Hefetz and Warner (2012) (citizen interest) Bel and Fageda (2007), Warner and Hebdon (2001) (unionization)
	Ideological Attitudes	Bel and Fageda (2007), 2008, 2009, Warner and Hebdon (2001), Hefetz et al., (2012)
	Political Factors	Bel and Fageda (2007), 2008, 2009, Warner and Hebdon (2001), Hefetz et al., (2012), Gradus et al., (2014), Picazo-Tadeo et al., (2012), Joassart-Marcelli and Musso (2005)
Financial Factors	Fiscal Stress/Debt Levels	Levin and Tadelis (2010) (debt levels) Bel and Fageda (2007), 2008, 2009, Picazo-Tadeo et al., (2012), Joassart-Marcelli and Musso (2005), Warner and Hefetz (2012), Warner and Hebdon (2001)
	Income/Expenditures	Warner and Hebdon (2001), Bel and Fageda (2007), Gradus et al., (2014), Hefetz et al., (2012)
Pragmatic/Managerial Factors	Information	Bel and Fagden (2008), Bel and Warner (2008), Warner and Hebdon (2001), Warner and Hebdon (2001)
	Information/Monitoring	Hefetz et al., (2012), Warner and Hebdon (2001), Hefetz and Warner (2004), Warner and Hefetz (2012)
	Service Quality	Warner and Hebdon (2001), Hefetz and Warner (2012)
	Officials Experience	Warner and Hebdon (2001), Levin and Tadels et al., (2010), Hefetz et al., (2012), Joassart-Marcelli and Musso (2005)
	Market Structure	Hefetz and Warner (2004), Hefetz and Warner (2012), Warner and Hefetz (2012)

Table A2
Mix of System Types for Cities Served by Multiple Water Systems (n = 103)

	System Mix	Number of Cities with Mix (%)
One System Type	Only Special Districts	23 (22.3%)
	Only Mutuals	1 (0.97%)
	Only IOUs	6 (5.8%)
	Only Other Cities	1 (0.97%)
Mix with City Run System	City Run, Special District	14 (13.6%)
	City Run, IOU	8 (7.8%)
	City Run, Mutual	4 (3.9%)
	City Run, Mutual, Special District	1 (0.97%)
	City Run, IOU, Mutual	3 (2.9%)
	City Run, IOU, Other City	2 (1.9%)
	City Run, IOU, Special District	4 (3.9%)
	City Run, IOU, Mutual, Other City	1 (0.97%)
	City Run, IOU, Mutual, Special District	1 (0.97%)
Mix without City Run System	IOU, Special District	12 (11.7%)
	IOU, Other City	2 (1.9%)
	IOU, Mutual	2 (1.9%)
	IOU, Mutual, Special District	7 (6.8%)
	IOU, Other City, Special District	1 (0.97%)
	IOU, Mutual, Other City, Special District	3 (2.9%)
	Mutual, Special District	6 (5.8%)
	Other City, Special District	1 (0.97%)

Table A3
California City Characteristics (unless otherwise stated, numbers are percent of cities with that characteristic with the number of systems in parentheses)

Variable	Non City-Run (n = 210)	City-Run (n = 272)	Overall Trends (n = 482)	Source
Incorporation Date*	Average: 1947 Median 1957	Average: 1913 Median 1908	Average: 1928 Median 1918	CA Association of Local Agency Formation Commissions
City Structure*	Council Manager 99% (208) Strong Mayor 0.5% (1) Weak Mayor 0.5% (1) Commission 0%	Council Manager 96% (260) Strong Mayor 1% (4) Weak Mayor 1% (3) Commission 2% (5)	Council-Manager 97% (468) Strong Mayor 1% (5) Weak Mayor 0.8% (4) Commission 1% (5)	California Municipal Democracy Index 2016 (California Common Cause)
Founding Law	Charter 21% (45) General Law 79% (165)	Charter 28% (76) General Law 72% (196)	Charter 25% (121) General Law 75% (361)	League of California Cities
Population	Average: 50, 295 Median: 30,640	Average: 83, 387 Median: 30,467	Average: 68, 448 (Median 30, 416)	U.S. Census
Race/Ethnicity*	Average: 37.80% Median: 30.95%	Average: 50.10% Median: 46%	Average: 44.4% Median 39.8%	U.S. Census
Median Household Income*	Average: $90, 406 Median: $81,792	Average: $66,240 Median: $61, 834	Average: $76,677 Median $68,333	U.S. Census
Democratic Voters	Average: 59.33% Median: 59.50%	Average: 59.56% Median: 61.45%	Average: 59.54% Median 60.74%	California Secretary of State
Enterprise Funds*	Have Water EF: 7% (14) Have Other EF: 46% (96)	Have Water EF: 97% (265) Have Other EFs: 91% (248)	Have Water EF 58% (279) Have Other EFs 71% (344)	CA State Controller's Office
City-Level Financial Risk*	Low 53% (112) Moderate 42% (88) High 5% (10)	Low 40% (110) Moderate 56% (151) High 4% (10)	Low 46% (222) Moderate 50% (239) High 4% (20)	California State Auditor's Office

*Signifies a significant bivariate correlation (p-value <.05) between the factor and whether a city runs its own water system (see Appendix Table A-4) (performed in Stata 15.1).

Appendix A4
Correlations of Variables

	Binary City Run System	Number of Water Systems
Los Angeles County	−0.0772	**0.2669*****
OC/Ventura MSAs	−0.0266	0.0444
Riverside-San Bernardino MSAs	**−0.1058***	0.0744
San Francisco-Bay Area MSA	**−0.2146*****	−0.0411
San Diego MSA	**−0.1138***	−0.0277
Sacramento MSA	−0.0155	−0.0004
Incorporation Date	**−0.4160*****	**0.1919*****
Number of Annexations (1980–2019)	−0.0273	−0.0231
Acreage of Annexations (1980–2019)	**0.1109***	0.0377
Population Change (Incorporation to 2018)	**0.1202****	−0.0328
Council Manager	**−0.1021***	0.0588
Charter City	0.0745	−0.0241

(continued on next page)

Appendix A4 (*continued*)

	Binary City Run System	Number of Water Systems
Population 2018 (1000s)	0.0796	0.0257
Percent Pop Nonwhite	**0.2472*****	**0.1065***
Household Median Income (1000s)	**−0.3302*****	0.0218
Percent Democratic Voters 2016	−0.0008	0.0259
Number of Non-Water Enterprise Funds	**0.5177*****	**−0.1601*****
Financial Risk Level	**0.1013***	0.0024

p < .05(*), p < .01(**), p < .001(***).

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