INEFFICIENCIES IN LOCAL INFRASTRUCTURE: EVIDENCE FROM DRINKING WATER IN CALIFORNIA

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Abstract. Local elected officials oversee critical infrastructure investments, yet their decisions may not align with residents' welfare. Using new data on investment and performance for California's municipal drinking water utilities, we show that pollution is higher in jurisdictions with weaker electoral accountability, measured by the frequency of contested elections and the presence of local media. We develop and estimate a dynamic model in which residents value water quality heterogeneously and vote accordingly, while office-seeking politicians trade off administrative costs against re-election incentives when choosing investments. We identify resident preferences using housing transactions at jurisdictional boundaries and recover electoral incentives from variation in voter welfare gains from investment. Increasing electoral accountability reallocates investment toward high-need jurisdictions, reduces pollution, and generates progressive welfare gains. By directing resources toward high-return investments, greater accountability also enhances the effectiveness of federal and state subsidies.

1. Introduction

Infrastructure investment in the United States is a growing concern, as spending has struggled to keep pace with an aging capital stock. Local governments oversee roughly half a trillion dollars in annual transportation and water infrastructure spending, yet citizens' ability to reward and punish politicians through elections—what we term *electoral accountability*—is often limited (Berry, 2009). When electoral oversight is weak, public investment decisions may diverge from residents' needs. This paper

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quantifies how electoral accountability shapes the allocation of infrastructure investment, affects the effectiveness of large-scale public subsidies, and ultimately impacts welfare.

We study drinking water infrastructure in California. Despite substantial federal and state funding, including $41.1 billion allocated since 1996 through Safe Drinking Water Act programs, chronic underinvestment persists, with measurable health consequences (Allaire et al., 2018; DiSalvo and Hill, 2024; Keiser et al., 2023). These challenges suggest that the problem goes beyond fiscal capacity. Drinking water systems are typically governed by locally elected officials, but these offices are frequently uncontested, and incumbents win most contested races.

We assemble a unique, comprehensive dataset linking drinking water system investments and their costs, contaminant readings and violations, election outcomes, local media presence, and housing transactions for California jurisdictions from 2003 to 2022. We first document that features of the political environment that shape electoral accountability are systematically associated with water quality. In particular, jurisdictions with a lower likelihood of contested elections and weaker local media presence exhibit significantly higher pollution levels, even after controlling for demographics, water system characteristics, and county and year fixed effects. To move beyond cross-sectional comparisons, we exploit within-jurisdiction changes in election timing and show that shifts to on-cycle elections—which increase the likelihood of contested races—lead to sustained reductions in pollution. Finally, leveraging time-series variation in federal and state funding expansions, we find that exogenous increases in funding raise investment, with significantly stronger responses in jurisdictions with greater electoral accountability. These results suggest that accountability improves the alignment between public investment and local welfare needs.

In light of these findings, we develop and estimate a dynamic model of office-seeking policymakers who choose infrastructure investment each period. Investment improves water quality with persistent but depreciating effects and must be financed through subsequent water-rate increases. Residents, who differ in their willingness to pay for quality improvements, cast ballots based on period-to-period changes in their own utility, provided that the election is contested and they turn out. The long-lived policymaker thus faces a dynamic trade-off: investing can raise re-election prospects by improving constituents' welfare in the future, but may entail substantial cost of time and efforts required to plan and implement the investment. Per-period payoffs balance residents' preferences against these costs, with the weight placed on

residents' welfare determined by the electoral incentives and the institutional features that shape them—such as the likelihood of contested elections, relative turnout rates, and the salience of water issues.

Identification requires separating policymakers' objectives from voters' preferences and, within policymakers' payoffs, disentangling electoral incentives from private costs of undertaking investment. We estimate heterogeneous residents' willingness to pay for water quality by combining a housing choice model with a boundary discontinuity design that leverages discontinuities at water system boundaries, following Bayer, Ferreira and McMillan (2007). We measure the causal impact of investment on pollution and water rate using an event-study design. Together, these components identify the voters' welfare gains of infrastructure investment.

To isolate electoral incentives within policymakers' objectives, we exploit variation in voters' aggregate net benefit of investments for water quality improvements. Specifically, we leverage exogenous shifts in residents' valuation of investment, which is fundamentally determined by the underlying water quality and the prevailing water rates. This valuation evolves over time due to fluctuations in environmental conditions that affect pollution levels, and it varies across jurisdictions based on factors such as the primary water source. Because policymakers observe these state variables and anticipate their implications for resident welfare when making infrastructure decisions, these shifts in the electorate's aggregate demand for investment allow us to identify the specific weight that residents' preferences carry in the policymaker's objective function.

Our structural estimates indicate that investments reduce water quality violations by 27% in years three through eight following investment. On average, investments increase annual household water rates by approximately $24 (2020 dollars) over the first decade, with substantial heterogeneity across jurisdictions depending on their typical financing structure for investment. Residents' median willingness to pay for a one-standard-deviation improvement in water quality is $66 per household per year. Combining estimated benefits and costs reveals substantial underinvestment: for roughly 39% of governments—serving 64% of Californians—additional investment yields positive net benefits averaging $42 per household annually, with benefits approximately 4.5 times costs. We find that this underinvestment is more prevalent where electoral competition is weaker.

Our results show that politicians do respond to resident preferences, placing substantially greater weight on residents' welfare in governments with more frequent

contested elections, even after accounting for administrative and technical constraints. At the same time, these constraints limit investment decisions, particularly in smaller systems with fewer skilled personnel capable of managing complex capital investments.

We employ our estimated model to conduct counterfactual simulations with two goals. First, we quantify the extent of misallocation in infrastructure investment arising from limited electoral accountability. Second we assess how the limited accountability affects the effectiveness of federal and state infrastructure subsidies. To quantify the misallocation in investment derived from the lack of accountability, we consider a counterfactual in which accountability is raised to a plausible upper bound, corresponding to governments that faced consistently contested elections, and solve for the resulting investment policies. The counterfactual reallocates investment toward jurisdictions with the greatest underlying pollution, aligning capital spending more closely with locally specific marginal welfare gains. In the most pollution-prone quintile, investment probabilities rise by more than 25 percent relative to baseline levels, leading to pollution reductions of up to 0.35 standard deviations. By contrast, investment declines modestly in cleaner jurisdictions where marginal benefits are lower. These changes translate into economically meaningful welfare gains: in the most pollution-prone jurisdictions, average household welfare increases by up to $20 per year.

Greater accountability also strengthens the effectiveness of existing federal and state subsidies. In the counterfactual, pollution reductions from current subsidy programs increase by approximately 37 percent on average and by nearly 50 percent in the most polluted systems under greater electoral accountability. In particular, we find that the lack of accountability undermines the targeting of these programs, decoupling subsidy take-up from welfare returns. While decentralization is often justified by local governments' superior information about heterogeneous community needs (Oates, 1972), our results show that this informational advantage translates into efficient targeting only when policymakers are electorally disciplined. Electoral accountability therefore affects not only local investment choices but also enhances the return to large-scale federal and state water infrastructure programs, with larger gains in jurisdictions facing the highest environmental need.

1.1. **Literature review.** A growing literature studies whether decentralized infrastructure decisions are efficient, in the context of schools (Cellini et al., 2010; Biasi et

al., 2025), ports (Brancaccio et al., 2024), high-speed rail (Fajgelbaum et al., 2023), drinking water systems (Sileo, 2023), and wind farm siting (Kashner, 2026). Measuring efficiency requires quantifying both the benefits and the costs of investment. We estimate benefits using housing-based measures of residents' willingness to pay for water quality, similar to Cellini et al. (2010), Biasi et al. (2025), and Kashner (2026). On the cost side, we leverage detailed data on drinking water quality, water charges, and local governments' financing of infrastructure projects.

We move beyond measuring inefficiency to investigating its causes, with a focus on electoral accountability. We show that local electoral accountability affects both water quality and the effectiveness of federal subsidies, which motivates an examination of how *office-seeking* officials choose investments.[1] Whereas existing research highlights external constraints on public utilities—such as rate-of-return regulation (Lim and Yurukoglu, 2018; Gowrisankaran et al., 2024) or regulated pricing (Timmins, 2002)—we focus on distortions arising from politicians' welfare weights and capacity constraints in executing large capital projects.

A central contribution of the paper is the estimation of policymakers' objective functions from observed investment decisions. Our approach exploits variation in the welfare gains from investment across constituents, combining residents' willingness to pay with the effects of investment on water quality and rates. Cross-sectional variation arises from heterogeneous willingness to pay across income groups and differences in jurisdictions' income composition, in the spirit of Mian et al. (2010). Within jurisdictions, migration, electoral rule changes, and exogenous shocks to pollution shift the composition of participating voters and thus the aggregate welfare return to investment. Because investment decisions recur over time, this panel structure provides an additional source of variation to identify policymakers' responsiveness to constituent welfare. This approach complement strategies that rely on exogenous shifts in electoral incentives, such as term limits (Besley and Case, 1995; List and Sturm, 2006; Sieg and Yoon, 2017; Aruoba et al., 2019; Sieg and Yoon, 2022), anti-corruption reforms (Avis et al., 2018), or campaign dynamics (Iaryczower et al., 2024).

[1]Previous studies have focused on politician rent-seeking and favoritism (Avis et al., 2018; Burgess et al., 2015), myopic voters (Healy and Malhotra, 2009), information disclosure (Bennear and Olmstead, 2008), time consistency (Lim and Yurukoglu, 2018; Ouazad and Kahn, 2025), cross-jurisdiction spillover (Bordeu, 2023), constituent political preferences (Fajgelbaum et al., 2023), and debt market frictions (Adelino et al., 2017; Agrawal and Kim, 2022).

Closely related is Fajgelbaum et al. (2023), who study how political preferences shape the spatial design of California's high-speed rail. Using voting data and a quantitative spatial model, they recover political weights from observed policy choices. We share their revealed-preference approach to identifying political objectives. However, our setting differs along several dimensions. First, whereas they analyze a one-time statewide referendum and centralized project design, we study repeated decentralized investment decisions by locally elected officials. Second, we directly quantify electoral accountability by estimating how policymakers' responsiveness to constituent welfare varies with electoral competition. Third, we show that imperfect accountability distorts not only investment allocation but also the effectiveness of public subsidies, expanding on recent research demonstrating the effectiveness of federally funded drinking water investments (Keiser et al., 2023). These distinctions allow us to analyze dynamic political agency and fiscal misallocation in routine public investment rather than a single high-salience project.

Finally, this paper builds on a long tradition of using structural models to recover preferences for local amenities, including schools (Bayer et al., 2007), air pollution (Tra, 2010; Bayer et al., 2016), transportation networks (Barwick et al., 2024). We contribute to this literature by introducing a new endogenous channel for the evolution of these local amenities. Rather than arising from residential resorting, as in Bayer et al. (2016); Almagro and Domínguez-Iino (2025), changes in local amenities in our setting are driven by endogenous infrastructure investment decisions made by local policymakers, whose responsiveness to residents' preferences depends on electoral incentives.

2. Drinking water infrastructure

This section describes the institutional environment governing drinking-water infrastructure investment in California. We first outline the basic operations of municipal water utilities. We then discuss how these investments are financed, emphasizing the central role of water service revenues. Next, we describe the local governance structure and electoral institutions under which water utilities operate. Finally, we review the regulatory framework established by the Safe Drinking Water Act and the federal and state subsidy programs that support infrastructure investment. Together, these institutional features shape both the costs and political incentives associated with drinking-water infrastructure provision.

2.1. **Water utility operations.** Water utilities, typically run by local governments like cities, manage three critical operations. First, they source raw water by pumping it from surface water bodies like lakes and rivers, or from underground aquifers. Second, they process this water through treatment facilities to ensure it meets safety standards for human consumption. Third, they maintain storage systems and distribution networks to provide consumers with reliable, uninterrupted access to water. These operations depend on extensive infrastructure that demands ongoing financial investment and regular maintenance to function effectively.

2.2. **Financing water infrastructure.** To fund infrastructure investments, local governments can choose between debt financing or pay-as-you-go funding, with both methods primarily relying on revenue from water services. This reflects the institutional structure of municipal water operations as enterprise utilities that operate separately from general government finances. Unlike other government services that are supported by tax revenue, water services are funded through user charges, and any financing arrangements for water infrastructure projects are ultimately secured by these water-related revenues (Posenau, 2021). As a result, new infrastructure investments typically necessitate higher water charges. Importantly, this implies that the relevant cost of water infrastructure investment arises from the increase in user charges needed to finance the project, rather than from foregone spending on other municipal services such as policing or education.

In California, water rates face strict regulatory oversight. Proposition 218 empowers property owners to block water rate increases, while cost-of-service requirements limit price differentiation across households. These constraints result in simple pricing structures among water systems in our sample: 45% use uniform pricing (flat fixed and service charges), while 55% employ tiered systems with modest usage-based price variation. Even when water charges must increase to cover investments, regulatory requirements mandate that revenue increases be distributed proportionally across rate components based on customer service levels.[2]

2.3. **Local governance and electoral institutions.** In California, 84% of the population is served by local governments.While professional general managers oversee technical and day-to-day operations, the ultimate authority over capital investment

[2]This is referred to as the proportionality requirement of property related fees, stipulated in Proposition 218 (see Article XIII D Section 6 of the California Constitution). See, as an example, a recent water rate study for the city of Madera (Madera, 2022).

and rate-setting lies with local governments' elected bodies. Depending on the institutional structure, they fall into three categories: cities, dependent special districts, and independent special districts. Independent special districts are autonomous entities governed by directly elected boards. In contrast, dependent special districts are tied to a city or county, with governance typically exercised by city council members or county supervisors who oversee budgets and operations. Across all governance types, governing bodies—city councils, county boards of supervisors, and independent special district boards—are multiple-member, usually five to seven officials.[3]

Many elections for these local officials are uncontested or feature only a single candidate, and voter engagement in these contests is often low.[4] Election timing varies across jurisdictions and over time, with some elections held off-cycle (e.g., in odd-numbered years) and others consolidated with statewide or national elections. Institutional changes, including the California Voter Participation Act enacted in 2015, have led many jurisdictions to shift toward on-cycle elections. This law restricts local governments from holding off-cycle elections if doing so results in substantially lower voter turnout. In addition, some local governments had already chosen to shift the timing of their elections prior to the law.

2.4. **Water quality regulation and infrastructure subsidies.** The 1974 Safe Drinking Water Act (as amended in 1996) regulates about 90 pollutants by maximum contaminant levels (MCL), and mandates timely public notifications of violations: within 24 hours for acute health risks like E.coli (Tier I), and within 30 days for all other MCL violations (Tier II).

In addition to the regulatory standards for drinking water quality, the federal and state governments has provided substantial financial support to help local systems meet these requirements. Over the past 25 years, the Drinking Water State Revolving Fund (DWSRF) has served as the primary vehicle for this support, providing more than $40 billion in subsidized financing since its inception in 1997 (EPA, 2019). This funding was expanded through the American Recovery and Reinvestment Act of 2009, and more recently, the Infrastructure Investment and Jobs Act of 2021.[5] In California,

[3]Most cities in California operate under a council-manager system, in which the city council appoints a professional city manager to oversee day-to-day operations.

[4]These elections consistently see voter participation rates at only half the level of national elections, with even lower turnout when they are not synchronized with presidential or gubernatorial races (Hajnal and Lewis, 2003).

[5]The latter allocated approximately $50 billion for water infrastructure nationwide, including substantial additional funding for the DWSRF, although this expansion falls outside our study period.

four statewide general obligation bond measures—Propositions 50 (2002), 84 (2006), 1 (2014), and 68 (2018)—have authorized billions of dollars for water quality and supply investments. More recently, California Senate Bill 200 (2019) created the Safe and Affordable Drinking Water Fund, which provides approximately $130 million annually to support safe drinking water projects.

By channeling large amounts of capital through low-interest loans and grants, these programs reduce the effective cost of drinking-water infrastructure investment, implying that observed water-rate increases capture only a fraction of the true economic cost of providing safe drinking water. Importantly, the availability and intensity of such subsidies vary considerably across jurisdictions and over time, creating meaningful variation in the effective cost of infrastructure investment faced by local governments and their residents. For example, communities that are designed as "disadvantaged" may qualify for additional financial support, including zero-interest loans or principal forgiveness, and in California, the designation is based on the median household income in a water system's service area.

3. Data

We construct an comprehensive database of drinking water infrastructure investment and enrich it by integrating information on water quality, utility rates, municipal finances, local political conditions, housing market transactions, demographic and socioeconomic characteristics, and climate. This combined dataset enables a detailed analysis of both the determinants and consequences of infrastructure investment. Below, we describe our data sources and key variables.

3.1. **Data sources.**

Our data construction relies primarily on California's Financial Transactions Reports (FTR), mandatory annual GAAP-compliant financial statements filed by local governments. These reports provide detailed information on revenues, expenditures, and capital outlays, from which we extract water enterprise-specific measures. To more comprehensively capture infrastructure investment, we augment the FTR data with records from the California Debt and Investment Advisory Commission (CDIAC) and the EPA's State Revolving Fund (SRF) programs, the latter obtained through FOIA requests.

We measure water quality using pollution data from the California Division of Drinking Water, which reports test results for more than 70 federally regulated contaminants at the public water system (PWS) level. We complement these data with

records of Safe Drinking Water Act violations from the U.S. Environmental Protection Agency (EPA). To link PWSs to their corresponding municipalities, we combine manual name matching, online verification, and institutional classification data from Dobbin et al. (2023).

To characterize the political environment shaping accountability, we focus on two dimensions: electoral competition and information availability. For competition, we identify whether elections for officials responsible for water investment are contested. City-level election data come from the California Election Data Archive (CEDA), while data for special districts are compiled from county election offices. For information, we measure local newspaper presence using the 3DLNews dataset (Ariyarathne and Nwala, 2024), which aggregates local news sources between 1996 and 2024 based on Google and Twitter scraping. We restrict attention to newspapers identified from Google search queries. Finally, we measure the composition of the electorate at the jurisdiction level using individual-level voter registration data from L2, which covers the universe of registered voters and tracks turnout across federal, state, and local elections. The data include demographic and socioeconomic characteristics, such as income proxies.[6]

To measure local governments' administrative capacity, we use the California Government Compensation (GCC) database, which provides comprehensive information on public employees across all local governments, including job titles, compensation, and employment status.

To capture residents' preferences over water quality, we use CoreLogic housing transaction data, which we link to buyer characteristics from Home Mortgage Disclosure Act (HMDA) records and to tract-to-tract commuting patterns from Longitudinal Employer-Household Dynamics (LEHD) data. Finally, we incorporate demographic and socioeconomic characteristics from the American Community Survey, mapped to municipalities using water service area boundaries from the California State Water Resources Control Board. We also include municipality-level precipitation measures from climate data sources.

3.2. **Scope of analysis.** We focus on cities and special districts that report water enterprise revenues and operate public water systems during the study period.[7] We further restrict the sample to entities primarily engaged in supplying water to local

[6]Since the income reported by L2 is notoriously unreliable, we assign each voter the average income based on the block group of their address, and their gender and age.
[7]Six county governments meet these criteria but are excluded from the analysis.

residents, rather than those focused on wholesale transactions or sales to business, industrial, or irrigation users.[8] Finally, we exclude 25 local governments due to missing data (e.g., water rate information or parent government identifiers for dependent special districts) or because they serve fewer than 50 households. The resulting sample consists of 716 local governments, including 261 cities (serving approximately 20 million residents) and 454 special districts (serving about 14 million residents). The majority of special districts (80%) are independent, while all dependent special districts in the sample are affiliated with county governments.

3.3. **Drinking water infrastructure investment.** Our novel dataset tracks California local governments' drinking water infrastructure investments, including investment frequency and funding sources. To our knowledge, this provides the first comprehensive view of local government infrastructure investment behavior on drinking water, expanding on prior work by Posenau (2021) and Sileo (2023).[9]

To identify infrastructure investment, we combine multiple sources of financing data (see Appendix A.1 for details). We first use indebtedness records from the FTR and cross-reference them with bond and loan issuance data from CDIAC to identify debt-financed investment. We then incorporate external funding sources using intergovernmental transfers reported in FTR water enterprise income statements and Drinking Water State Revolving Fund (DWSRF) loan and grant records.[10] We aggregate all sources of financing—including debt, federal and state loans, and grants—to construct total investment funding at the jurisdiction-year level.[11] We define an investment event when total funding exceeds a minimum threshold, $500,000 (in 2020 dollars) to capture economically meaningful projects.[12] This approach relies on the

[8]Specifically, we require that less than 25% of water revenues come from wholesale sales (including sales to other municipalities), less than 25% of retail water revenues come from sales to business, industrial, or irrigation users, and that average annual water sales exceed $15,000 in nominal terms.
[9]Posenau (2021) examines water utilities' debt contracts using our data sources, but doesn't investigate infrastructure investment choices. Sileo (2023) leverages Kentucky's Water Resource Information System (WRIS) to compile data on water systems and infrastructure projects, but does not study water service charges or the source of funding.
[10]Specifically, FTR and CDIAC provide information on each debt instrument's principal amount, issuance year, stated purpose, pledged revenue sources, and any federal or state involvement. For external funding, we combine intergovernmental transfer records from FTR income statements with EPA DWSRF loan and grant data.
[11]Because financing may occur over multiple consecutive years, we group contiguous years with positive funding into investment spells, assign the first year of the spell as the investment year, and sum funding within the spell to obtain total investment.
[12]Our main results are robust to alternative thresholds.

TABLE 1. Summary statistics

	Cities	Special districts
A. Infrastructure investment		
Annual investment frequency	0.069	0.049
Conditional on any investment		
Amount debt-financed or externally funded		
Mean (in $ millions)	131.68	48.01
Median (in $ millions)	13.53	6.96
Per household, Mean (in $)	3,481	7,971
Per household, Median (in $)	1,755	2,031
% financed via debts (vs. grants)	66.21	57.92
B. Annual cost of water per household		
Mean (in $)	792.6 (500.3)	753.6 (479.3)
Median (in $)	638.3	616.9
C. Water pollution		
Pollution measure > 0	0.260	0.199
EPA - Tier I	0.005	0.008
EPA - Tier II	0.065	0.084
D. Political environment		
Fraction of contested elections	0.897	0.434
Fraction of on-cycle elections	0.833	0.637
Local newspaper presence (within 20 miles)	0.935	0.860
Local newspaper presence (within 10 miles)	0.820	0.622
Avg. number of skilled employees	29.23	11.46
Number of governments	261	454

Notes. This table presents summary statics of key variables used in our analysis, based on the 261 cities and 454 special districts that provide drinking water services, for the period of 2003-2022. The mean values are presented with standard deviations in parentheses, unless stated otherwise. All investment amounts and rates are adjusted to 2020 dollars using CPI. †: These conditional statistics are for municipalities that made at least one investment during the study period, and are based on the *total* debt financing and external funding across all investments per municipality.

premise that municipalities rarely finance infrastructure projects entirely from internal resources.[13]

Table 1 presents summary statistics separately for cities and special districts. Investment activity is relatively infrequent: in any given year, about 7% of cities and 5% of special districts undertake an investment. Among those that do invest, the median combined funding from debt and external sources is $13.5 million for cities and $6.9 million for special districts (in 2020 dollars). In contrast, mean values are

[13]Using post-2017 FTR data for cities, which separately records equity-financed capital investment in water enterprises, we confirm this premise: the probability of an above-mean investment occurring without debt financing or external funding is only 1.3%.

substantially higher—$131.7 million and $48 million, respectively—indicating considerable right-skew in the distribution. A similar pattern appears in per-household terms: for special districts, the median investment of $2,031 per household is well below the mean of $7,971. Municipalities typically finance infrastructure through a combination of internal funds, debt, and external sources such as grants. We estimate that debt instruments—including municipal bonds and government loans—account for 66% of investment costs for cities and 58% for special districts.[14]

3.4. **Drinking water rates.** As described in Section 2.2, local governments finance water infrastructure investment through user fees and charges. Therefore, to assess the financial burden on water service users, we calculate the per-household cost by dividing the annual total of residential sales (from FTR water enterprise income statements) by the number of households in each municipality's water service area.[15] Panel B in Table 1 reveals a median annual cost of $638 per household for cities and $617 for special districts in 2020 dollars, with means exceeding these values in both cases. Notably, these costs show substantial variation across municipalities, as evidenced by large standard deviations.

3.5. **Drinking water quality.** Panel C of Table 1 reports summary statistics on drinking water pollution in California systems. For any given pollutant-system pair, the annual probability that contaminant levels exceed the federal Maximum Contaminant Level (MCL) is relatively low. However, when aggregating across multiple pollutants, exceedances are not uncommon: in a given year, 26% of cities and 19.9% of special districts have at least one contaminant above the MCL. EPA violations also occur regularly, with 6.5% of cities and 8.4% of special districts experiencing Tier II violations in a typical year. In contrast, more severe Tier I violations are rare, occurring in less than 1% of observations for both cities and special districts.

[14]These figures are consistent with practitioner estimates of roughly 65% debt financing (Hansen and Mullin, 2022).

[15]Both FTR and the California Electronic Annual Reports (eAR) provide data on the number of households served by each public water system, but coverage is inconsistent. To address this, we instead estimate the number of households in each municipality using data from the American Community Survey combined with municipal shapefiles. We then use this measure to construct per-household residential water sales revenue. The eAR data also report average water rates for each public water system, though availability is similarly uneven. As a result, when our primary water rate measure falls outside a plausible range and eAR rate data are available, we substitute in the eAR-based rates. To validate our water rate measure, we directly contacted individual water utilities to obtain current rate schedules and documentation from rate hearing proceedings.

Given that water pollution is measured in multiple dimensions, we aggregate these measurements into an index. The water pollution at system i during year t, denoted by q_{it}, is the sum of an indicator for EPA violations and an indicator for each pollutant c's concentration reading (q_{cit}) above the maximum contaminant level (MCL_{ct}), divided by the total number of pollutants plus one:

$$q_{it} = \frac{\mathbf{1}\{\text{EPA violation}_{it}\} + \sum_c \mathbf{1}\{q_{cit} > MCL_{ct}\}}{1 + \#\text{ pollutants measured}_t}. \tag{1}$$

Here we exclude disinfection byproducts, and thus the denominator for this measure is around 71. Unless noted otherwise, we use this measure throughout the study.[16]

3.6. **Political environment for accountability.** Panel D of Table 1 reports the share of contested elections and the share of on-cycle elections for seats on the governing bodies of cities and special districts that provide drinking water, respectively.[17] There is substantial variation across entity types. Many local elections are uncontested, allowing incumbents to retain office by default, and this pattern is particularly pronounced among independent special districts (69% compared to 8% for dependent special districts and 10% for cities). For example, in Santa Fe Springs, every city council election from 2003-2022 was contested, whereas the Ponderosa Community Services District held only two board elections over the same period. Regarding election timing, on-cycle elections constitute the majority (71%), though off-cycle elections remain common. In our sample, 85 local governments always held off-cycle elections, while 58 governments switched to on-cycle elections before 2018, when the California Voter Participation Act became effective, and 57 governments switched in or after 2018.

Panel D of Table 1 also summarizes the extent of local newspaper presence across jurisdictions during the study period. For each year, we classify a newspaper organization as *active* if it publishes at least 10 articles in the dataset. We then measure local news presence by counting, for each jurisdiction-year, the number of active newspaper organizations headquartered within a 20-mile radius that overlaps with the jurisdiction's service area, as defined by the California State Water Resources

[16]When the unit of analysis is the local government, we further aggregate this index for those that own multiple water systems, with the weight being the number of connections of each water system. In our sample, 89% of the local governments providing drinking water services to residents own a single water system.

[17]We use mayor and city council elections for cities, county supervisor elections for dependent special districts, and water board elections for independent special districts. We identify the parent government of each dependent special district using FTR data.

Control Board.[18] Based on this measure, 11% of local governments are never covered by a nearby newspaper.

We measure governmental manpower to facilitate the planning and implementation of capital investments in drinking water infrastructure by the presence of highly compensated and skilled employees for drinking water operations. Panel D of Table 1 shows that the average number of such skilled employees per government is 29.2 for cities and 11.5 for special districts.

4. Suggestive evidence for infrastructure under-investment

Building on the heterogeneity in political environments documented in Section 3.6 and leveraging our novel and comprehensive dataset, this section shows that local water pollution is systematically associated with features of the political environment that shape electoral incentives, while remaining plausibly orthogonal to the underlying costs and benefits of infrastructure investment. These patterns persist when exploiting within-jurisdiction panel variation. Taken together, the results point to meaningful misallocation in the provision of safe drinking water and are consistent with a role for political accountability in shaping how public officials respond to constituents' needs.

4.1. **Cross-sectional evidence.** Our analysis is at the jurisdiction-pollutant-year level, indexed by j, p, and t. The main outcome, Pollution_{pjt}, is measured as the share of tests exceeding the federal maximum contaminant level (MCL) for pollutant p in jurisdiction j and year t, allowing for comparisons across contaminants. Our key explanatory variable, Political Env_j, captures features of the local political environment that shape electoral accountability—specifically, the fraction of contested elections and the presence of local newspapers, as discussed in Section 3.6. We construct these measures at the jurisdiction level by averaging over the full sample period. Because the pollution measure is often zero but occasionally positive, we estimate a Poisson specification as follows:

$$\mathbb{E}[\text{Pollution}_{pjt}] = \exp\left(\beta \,\text{Political Env}_j \;+\; \mathbf{x}_{pjt}\alpha \;+\; \phi_{county(j)} \;+\; \mu_{pt}\right). \qquad (2)$$

The specification includes county and period-by-pollutant fixed effects, $\phi_{county(j)}$ and μ_{pt}, respectively, along with time-varying jurisdiction-level controls for demographic characteristics, water system attributes, and precipitation. We also account for

[18] In practice, we use the service area of a public water system. If a jurisdiction is served by multiple systems, we take the maximum count of active newspaper organizations across those systems.

TABLE 2. Electoral Competition matters for water quality

	Average % above MCL			
	(1)	(2)	(3)	(4)
Frequency of contested elections	-0.229*			
	(0.132)			
Any local newspaper within 20 miles		-0.327**		
		(0.145)		
Frequency of on-cycle elections			-0.384**	
			(0.127)	
Holding on-cycle elections				-0.121**
				(0.064)
Median household income (standardized)	-0.228***	-0.233**	-0.233**	-0.0701
	(0.066)	(0.065)	(0.065)	(0.068)
Demographics, system attributes	Yes	Yes	Yes	Yes
Precipitation stats	Yes	Yes	Yes	Yes
Pollutant-Year FE	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	No
Pollutant-Jurisdiction FE	No	No	No	Yes
Number of observations	346,196	346,196	346,196	346,196

Notes: This table reports regression estimates where the dependent variable is the fraction of pollution readings above MCL from public water systems, at the pollutant-government-year level, over the period 2003-2022. Standard errors, clustered at the government level, are shown in parentheses. Statistical significance is denoted by $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$. †. Additional controls include population served, primary water source (surface vs. groundwater), socio-economic covariates (% white, population density, age distribution), the fraction of readings conducted in each calendar month, and precipitation measures (mean, 75^{th} percentile, 90^{th} percentile, and the fraction of days with no rain).

differences in the distribution of measurements across months for each pollutant-jurisdiction pair. All observed time-varying jurisdiction-level and jurisdiction-pollutant characteristics are summarized in the vector $\mathbf{x}_{jt}$.

Table 2 shows that measures of political accountability are negatively associated with drinking water pollution. Jurisdictions with a higher frequency of contested elections and those with greater local newspaper presence exhibit significantly lower rates of pollution, even after controlling for factors that affect the underlying costs and benefits of infrastructure investment and water service. The magnitudes are economically meaningful. For example, the implied reduction in pollution associated with moving from no contested elections to fully contested elections is comparable to that associated with a one standard deviation increase in median household income (Column 1). Similarly, the presence of a nearby newspaper is associated with a sizable

decline in pollution (Column 2). These patterns highlight the quantitative importance of local accountability in shaping water quality outcomes.

A natural question is whether drinking-water quality is sufficiently salient to influence local electoral outcomes. Surveys indicate high public concern about drinking-water pollution, and in California advocacy organizations such as the Community Water Center Action Fund and Clean Water Action California seek to raise the political salience of drinking-water issues through voter education, candidate endorsements, and grassroots campaigns. Local newspapers may play a complementary role by providing coverage of water quality conditions and utility performance, thereby increasing the information available to residents. Consistent with these channels, our results suggest that jurisdictions with more active oversight and information dissemination exhibit lower levels of pollution, aligning more closely with constituent interests in safe drinking water.

4.2. **Exploiting panel-variation in election timing.** A causal interpretation of the patterns in Table 2 is limited because electoral accountability can be correlated with underlying jurisdiction characteristics that also shape residents' preferences for drinking water quality and the costs of infrastructure investment. As an example, older residents are more exposed to the risk of water pollution, and are also more likely to participate in local politics. To move beyond cross-sectional comparisons, we exploit jurisdictions that change their election timing over time, often in response to institutional reforms such as the California Voter Participation Act.

Election timing substantially changes the political environment in which local officials operate. Especially, we find that on-cycle elections are significantly more likely to be contested (Table C4 in Appendix C). To our knowledge, no prior study has examined how election timing affects whether local elections attract challengers. One potential mechanism is that candidate entry—especially in low-salience elections—is sensitive to the costs of running, which may be lower in on-cycle elections due to spillovers from concurrent campaigns, such as greater voter attention, easier fundraising, and party or group mobilization. At the same time, entry decisions may respond to voter-side effects of election timing. A well-established finding is that on-cycle elections generate higher turnout and a more representative electorate (Hajnal and Lewis, 2003; Hajnal et al., 2022), which could increase the expected returns to entry

and encourage challengers.[19] However, de Benedictis-Kessner (2018) shows that on-cycle elections are associated with a larger incumbency advantage, which may deter entry.[20] Which of these forces dominates remains an open question. For our purposes, we treat election timing as a change in the political environment which is exogenous to factors that affect the "efficient" level of investment such as its cost and value to residents.

We estimate a panel specification that replaces Political Env$_j$ with an indicator for whether jurisdiction j holds on-cycle elections in year t, while including pollutant-by-jurisdiction and pollutant-by-year fixed effects. This approach compares water quality within the same jurisdiction and pollutant before and after a shift to on-cycle elections. Column 4 in Table 2 presents the results. The estimated coefficient of -0.121 implies that moving elections on-cycle is associated with an approximately 12 percent reduction in the share of tests exceeding regulatory thresholds. This effect is economically meaningful: it corresponds to roughly half the magnitude of a one standard deviation increase in median household income in the cross-sectional specifications.

Taken together, the evidence in this section shows that features of the political environment that shape electoral accountability are systematically associated with drinking water quality, both in cross-sectional comparisons and when exploiting within-jurisdiction changes in election timing. We also provide complementary evidence that this relationship operates through elected officials' investment behavior in Appendix B, where we examine how local governments respond to exogenous variation in federal and state funding, shedding light on how electoral accountability shapes investment decisions. However, because both benefits and costs of infrastructure investment are difficult to measure directly, the evidence in this section alone cannot determine whether, and how much, the political environment to improve officials' accountability enhance welfare or investment choices. We therefore develop and estimate a structural model to quantify the net benefits of infrastructure investment, evaluate how electoral accountability shape investment efficiency, and explore the policy implications for infrastructure provision.

[19]Our data also confirms the relationship between turnout and election timing (Table C3).

[20]Notably, the incumbency advantage results in de Benedictis-Kessner (2018) are based on mayoral elections that are already contested. In our setting, incumbents' vote margins are *smaller* in a balanced panel where uncontested races are assigned a margin of one (Table C4 in Appendix C), whereas this pattern disappears when restricting to contested elections only.

5. Model

This section develops a model of an elected governing body's dynamic investment decisions in managing a jurisdiction's public drinking-water system. The governing body—e.g., a city council or special district board—comprises several members who face reelection on a staggered cycle. The jurisdiction's residents differ in how they value the trade-off between water quality and rates and, therefore, how they value investment—investment improves water quality, albeit at the cost of increased water rates. Residents therefore decide whether to retain or replace the members standing for election based on current outcomes—water pollution and rates—which reflect the governing body's past investment decisions. These elections are the key disciplining force to align the governing body's investment decision with residents' needs. Because a subset of seats is contested in any period, we model the governing body as a single decision maker solving an infinite-horizon problem, hereafter referred to as the *policymaker*.[21] Each resident i is characterized by income y_{it}.[22] Let F_{yt} denote the cross-sectional distribution of y in the jurisdiction in period t.

At the start of each period t, the policymaker chooses whether to undertake a capital investment, setting $a_t = 1$ if they proceed and $a_t = 0$ otherwise. During the period, the realized water quality $q_t \in \mathbb{R}_+$ and the per-resident cost of service $r_t \in \mathbb{R}_+$ (covering capital, operations, and maintenance) are publicly observed.[23] At the end of the period, an election occurs with probability ρ. If no election is held, the governing body's composition remains unchanged; otherwise, the next period's membership reflects the vote outcome. If the governing body is approved upon an election (i.e., the members up for reelection are retained), they obtain an extra benefit $\nu \geq 0$. Figure 1 summarizes the timeline.

5.1. **Voting and election outcomes.**

When an election occurs, resident i turns out with probability $\pi_t(y_{it})$; otherwise, she abstains. Abstracting from seat-specific

[21]The governing body is a committee whose members change over time, and we model that electoral risk and turnover scale continuation values rather than replacing the governing body entirely given that seats are staggered.

[22]The framework can accommodate richer, multidimensional resident heterogeneity in principle, but doing so would require additional variation in the data to separately identify preference parameters across multiple resident attributes.

[23]Given (i) a balanced-budget requirement that user revenues cover per-period costs, (ii) institutional and legal constraints (see Section 2), and (iii) inelastic demand, we assume that all residents pay the same amount r_t for their water services.

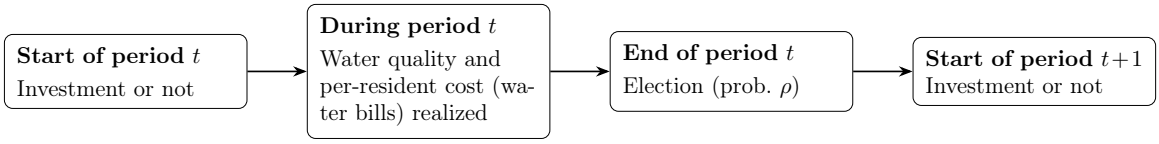


FIGURE 1. Timeline

contests within period t, we treat the event as a single election that either approves or disapproves the policymaker.

We parameterize resident i's trade-off between water quality and rates by $\omega(y_{it}) \in \mathbb{R}_+$, interpreted as her marginal willingness to pay for quality. The per-period utility from water service is

$$u(q_t, r_t, y_{it}) \;=\; \omega(y_{it})\, q_t \;-\; r_t.$$

Conditional on turning out, resident i votes for the policymaker if her utility from current water services is at least her benchmark utility plus an idiosyncratic preference shock for the challenger (e.g., charisma or valence), v_{it}:

$$u(q_t, r_t, y_{it}) \;\geq\; v_{it}.$$

The shock v_{it} is drawn from $F_{v(y_{it})}$, independent of water investments and outcomes.

Let $\tilde{\pi}_t(y_{it}) \equiv \pi_t(y_{it}) \big/ \int \pi_t(y')\, dF_{yt}(y')$ denote turnout weights. The vote share for the incumbent is

$$\tilde{\mu}_t \;=\; \int \tilde{\pi}_t(y)\, F_{v(y)}\big[u(q_t, r_t, y)\big]\, dF_{yt}(y).$$

Aggregate uncertainty in translating vote share into victory is captured by $\eta_t \sim F_\eta$ with mean zero; the incumbent wins iff $\tilde{\mu}_t - \eta_t \geq \frac{1}{2}$, so the winning probability is $F_\eta\big(\tilde{\mu}_t - \frac{1}{2}\big)$. If $v_{it} \sim \text{Unif}\Big[-\frac{1}{2\sigma_v}, \frac{1}{2\sigma_v}\Big]$ and $\eta_t \sim \text{Unif}\Big[-\frac{1}{2\sigma_\eta}, \frac{1}{2\sigma_\eta}\Big]$, then the winning probability is

$$\mu(q_t, r_t) \;=\; \frac{1}{2} \;+\; \sigma_\eta\, \sigma_v \int \tilde{\pi}_t(y)\, u(q_t, r_t, y)\, dF_{yt}(y), \tag{3}$$

provided the arguments lie within the corresponding supports.

5.2. **Water quality and rate dynamics.** Investment in infrastructure presents a fundamental trade-off for the system: it reduces pollution levels but simultaneously increases water rates for residents.

The observed water quality of the system at time t, denoted by q_t, is determined by the interaction between exogenous environmental conditions and the system's infrastructure. The endogenous component of water quality is governed by

the investment stock, which encapsulates the cumulative value of past infrastructure improvements. The investment stock l_t^q evolves according to:

$$l_{t+1}^q \;=\; \tau_q a_t + (1-\delta_q) l_t^q, \tag{4}$$

where the parameter $\delta_q \in [0,1]$ denotes functional depreciation of the investment stock due to operational wear, and τ_q captures the effectiveness of investment at reducing pollution. Specifically we assume that water quality is a positive continuous variable with conditional mean:

$$\mathbb{E}[q_t] \;=\; \exp(\alpha_t + l_t^q), \tag{5}$$

where α_t captures the expected level of water quality in the absence of investment, reflecting the fundamental quality of the water source which is determined by factors such as local geography and climate conditions.

The per-period, per-resident cost of service reflects both operating expenditures and the recovery of past capital investments. The latter is captured by l_t^r, the per-resident stock of unrecovered investment costs. This state variable represents the accumulated financial obligations or capital charges associated with infrastructure investments. Its evolution depends on parameters τ_r and δ_r, capturing the per-resident cost of new investment a_t and the rate at which these costs are amortized over time.

$$l_{t+1}^r = \tau_r a_t + (1-\delta_r) l_t^r. \tag{6}$$

Under this specification, the present discounted stream of per-resident total cost of investment is $\sum_t^\infty \tau_r (1-\delta_r)^t$. The per-resident water rate then evolves according to

$$r_t = \gamma_t + l_t^r + \zeta_t^r, \tag{7}$$

where γ_t captures the baseline, expected level of water rates, reflecting the jurisdictions' operating costs, in the absence of investment, and the shock ζ_t^r, with $\mathbb{E}(\zeta_t^r) = 0$, represents transitory operations/maintenance costs and is assumed to be serially uncorrelated.

5.3. **The policymaker's investment decision.** The private cost of investment borne by the policymaker is

$$\kappa + \epsilon_t,$$

where ϵ_t is an i.i.d. Logistic shock with unit scale capturing unobserved costs of planning and implementing investment. The payoff from not investing is normalized

to zero. This term reflects the cost of time and efforts required to plan and implement the investment.[24]

The policymaker chooses whether to incur this cost by weighing it against the risk of losing an election, which depends on the residents' welfare gains for investment. In particular, the policymaker's per-period utility is

$$\rho\mu(q_t, r_t)\nu - (\kappa + \epsilon_t)a. \tag{8}$$

Here the policymaker cares about residents' welfare gains for investment insofar it affects the probability of winning $\mu(q_t, r_t)$. Therefore, these electoral incentives discipline policymakers and help align their actions with constituent welfare. We summarize the institutional features that determine the strength of these incentives– election frequency (ρ), the value of holding office (ν), and the responsiveness of the electorate (σ_η, σ_v)– into a single parameter, λ:

$$\lambda \equiv \nu\,\rho\,\sigma_\eta\,\sigma_v, \tag{9}$$

so that we can rewrite the policymaker's per-period utility (8) as

$$\lambda \int \tilde{\pi}_t(y) u(q_t, r_t, y)\, dF_{yt}(y) - (\kappa + \epsilon_t)a. \tag{10}$$

We interpret λ as a (reduced-form) measure of political accountability— the weight that the politician places on resident welfare when making investment decisions. A lower value of λ implies a larger institutional wedge between policymaker incentives and constituent welfare, making investment less likely even when residents' aggregate willingness to pay exceeds the policymaker's private cost.

Let β denote the discount factor. Because the policymaker chooses the investment at the start of period t prior to the realization of water service outcomes, the public state is $\mathbf{s}_t \equiv (q_{t-1}, r_{t-1}, l^q_{t-1}, l^r_{t-1})$.

The expected value function can be rewritten as

$$V(\mathbf{s}_t) = \mathbb{E}_{\epsilon_t}\Bigg(\max_{a\in\{0,1\}} \Big\{ \lambda \int \tilde{\pi}_t(y)\, \mathbb{E}[u(q_t, r_t, y) \,|\, a, \mathbf{s}_t]\; dF_{yt}(y) - a\,(\kappa + \epsilon_t) \;+\; \beta\, \mathbb{E}[V(\mathbf{s}_{t+1}) \,|\, a, \mathbf{s}_t] \Big\} \Bigg). \tag{11}$$

[24] As discussed in Section 2, this cost does not reflect fiscal trade-offs with other municipal spending. Because water infrastructure is financed through water-service revenues rather than the general budget, the policymaker's private cost primarily captures administrative and political effort associated with undertaking the project.

Here, $\mathbb{E}_{\epsilon_t}(\cdot)$ averages over the contemporaneous shock ϵ_t; the inner expectations integrate over (q_t, r_t) induced by $(a, \mathbf{s}_t)$ and over the next-period state $\mathbf{s}_{t+1}$, respectively.

6. Identification and estimation procedure

Jurisdictions (cities and special districts) are indexed by j. In each year t, the policymaker in jurisdiction j chooses an investment decision $a_{jt} \in \{0, 1\}$. Let $\boldsymbol{x}_{jt}$ collect exogenous state variables that affect water quality and costs—e.g., system size and water source—as well as its governance structure (city, dependent special district, or independent special district). Data provide the realized investment decisions a_{jt}, from which the investment stocks (l^q_{jt}, l^r_{jt}) are constructed, as well as water quality q_{jt}, the per-resident water rate r_{jt}, and covariates $\boldsymbol{x}_{jt}$. We also observe the jurisdiction-year-specific distribution of resident income y, denoted by F_{yjt}. In addition, the data include information on voter turnout, elections, government finances related to loans and grants, and housing transactions and property attributes.

6.1. Overview.

The structural primitives fall into three groups. First, the resident-side primitives are the marginal willingness to pay for water quality $\omega(y)$ and voter turnout rate as a function of their income, $\pi_{jt}(y)$, which we allow to be jurisdiction-year-specific. Second, the government-side primitives are the policymaker's private cost of investing, κ_j and the weight they place on the constituents' utility λ_j, as well as the intertemporal discount factor, β. We focus on the composite wedge λ_j, which allows us to impose minimal assumptions on the specific mechanism. Finally, the state transition primitives consist of the parameters governing the effectiveness and durability of investment (τ_q, δ_q), the financial cost and amortization of investment (τ_r, δ_r), and the baseline water quality and rate, α_{jt} and γ_{jt}, that we recover for each year and jurisdiction.

Our estimation proceeds in three steps. Here we provide a brief overview and then subsequent sections describe each step of the estimation in detail. In the first step, we recover the income-specific turnout $\pi_{jt}(y)$ for each jurisdiction and election cycle from election occurrences and individual-level turnout records. We also recover the state transitions for water quality and rate from data on investment, water quality, and water rate. Using our detailed records on the sources of financing used for capital improvements, we allow investment-induced water rate increases to depend on the expected share of funding coming from state and federal grants rather than from borrowing.

Next, we recover the residents' marginal willingness to pay for water quality, $\omega(y)$. Note that jurisdiction-level investment decisions alone do not disentangle residents' preferences from policymakers' incentives. To address this, we use auxiliary housing transactions data and identify $\omega(y)$ from household sorting. Specifically, we implement a boundary discontinuity design (Black, 1999) nested within an equilibrium housing-demand framework following Bayer et al. (2007).[25]

In the last step, we recover the policymaker's private cost of investing, $\kappa(\boldsymbol{x})$, and the wedges $\lambda(\boldsymbol{x})$ from the observed investment decisions.

6.2. **Water quality transition estimation.** The parameters (τ_q, δ_q) capture the extent to which investment in water infrastructure can improve water quality over time. To recover these parameters, we begin by using a stacked event study approach to assess the impact of an investment across all investment events (Cengiz et al., 2019). For each investment event, e, we create an event-specific dataset, which includes observations from the treated government around the investment—between 3 years before and 16 years after the year of investment—and observations from all governments that did not have any major investments over the event window.[26] Since many readings are zero, we use a Poisson regression model with the conditional expectation as follows:

$$\mathbb{E}[q_{jte}|\{I^k_{jte}\}^{16}_{k=-3}, \boldsymbol{x}_{jt}] = \exp\left(\sum_{-3}^{16} \phi^q_k I^k_{jte} + \phi^q_x \boldsymbol{x}_{jt} + \psi^q_{je} + \mu^q_{te} + \eta^q_{jte}\right), \qquad (12)$$

where q_{jte} is the water quality measured at the drinking water facility of government j at year t, included in the e^{th} investment event dataset. The treatment dummy I^k_{jte} equals 1 if the investment event e occurred k years from year t by government j, and the specification includes event-specific government fixed effects and event-specific time effects, to ensure that identification comes from within an event.

We then map the estimated event study coefficients to the geometric decay process described in Equation (5) via non-linear least squares (NLS). Specifically, τ_q captures the initial impact of investment on pollution, while δ_q matches the persistence of the effect over time.

[25] An alternative approach would be to exploit election outcomes, but these confound the marginal willingness to pay $\omega(y)$ with issue salience and micro-level voting data for local elections are limited.
[26] Our results are robust to perturbations to the time window and weighting of the control group observations depending on the propensity score.

Having estimated the dynamic treatment effect of investment on pollution, we take two additional steps to discipline the law of motion of q. First, we estimate a panel model of expected pollution at the jurisdiction-year level as a function of jurisdiction fixed effects, year fixed effects, and time-varying characteristics such as weather conditions, abstracting from investment decisions. Second, we use the cumulative treatment effects implied by observed investments to back out the expected level of pollution in the absence of investment, α_{jt}:

$$\mathbb{E}[q_{jt}] = \exp\left(\alpha_{jt} + \sum_{e}\sum_{k=0}^{t-t_e} \hat{\phi}_k^q I_{jte}^k\right). \tag{13}$$

To determine the initial investment stock l^q, we exploit the fact that depreciation, governed by δ^q, limits the persistence of past investments. As a result, only a finite number of pre-sample periods must be considered to capture investments that may still affect current pollution and water rates. We thus construct investment histories for the period $1990-2002$ to initialize l_{jt}^q in $t = 2002$ for every jurisdiction. We follow the same approach to initialize the investment stock l_{jt}^r, which is used to estimate the water-rate transition process.

6.3. **Water rate transition estimation.** To estimate how investment costs are passed on to residents through water charges (Section 2), we combine a stacked event-study design, similar to that used in modeling water quality transitions, with additional structure to account for heterogeneity across governments and time. To allow for heterogeneity in federal and state funding, which substantially reduces the share of investment costs borne by residents, we estimate the water rate transition process separately for two groups based on the predicted borrowing amount per household. The borrowing among per household is predicted using the relationship between the observed borrowed among in realized investments and the government characteristics considered by federal and state authorities in allocating funds, such as income and population served.

Then, we divide the sample between high- and low- borrowing (respectively above and below median amount per household) and, denoting the two groups by b, for each investment event e we separately estimate

$$\log r_{jte} = \sum_{k=-3}^{16} \phi_k^r I_{jte}^k + \phi_x^r \boldsymbol{x}_{jt} + \psi_{je}^r + \mu_{te}^r + \eta_{jte}^q, \tag{14}$$

where r_{jte} is the per-resident water rate of government j in year t within the e^{th} event dataset, and $\phi_x^r \boldsymbol{x}_{jt}$ captures changes in ongoing maintenance and operating costs. Then, we use the estimated event study coefficients to calibrate a jurisdiction-year-specific parameter τ_j^r. For each borrowing group b, we calculate the average treatment effect on the log water rate over the first five years following an investment event. We then set τ_j^r equal to this average log- increase multiplied by the baseline water rate level.

6.4. **Estimation of resident preferences for water quality.** To recover the residents' value for quality, we rely on house transaction prices in California from 2003 to 2019, and follow Bayer et al. (2007).[27] By nesting a boundary discontinuity design (Black, 1999) within an equilibrium housing demand model, we leverage variation in water quality across public water systems.[28]

Consider a potential buyer i with income y_{it} choosing among houses h in a local housing market in year t. Houses vary in annualized transaction prices p_{ht}, physical and neighborhood characteristics $\boldsymbol{x}_{ht}$, the commuting distance to the buyer's workplace, d_{iht}. Each house is also located in a jurisdiction that supplies drinking water, denoted by $j(h)$, which determines the water quality $q_{j(h)t}$ and the annual water rate $r_{j(h)t}$. Houses may additionally differ in an unobserved quality component ξ_{ht}, which may be correlated with price. To account for time-varying unobserved neighborhood attributes that may influence both water pollution and unobserved quality, we include boundary-year fixed effects, $\psi_{b(h)t}$. These fixed effects are defined for houses located within 500 meters of water service jurisdiction boundary $b(h)$ in year t, and capture difference in amenities (other than the difference in water quality and rates) across jurisdictions.[29]

Buyer i's utility from purchasing house h in year t is

$$U_{iht} = \boldsymbol{\theta}_x \boldsymbol{x}_{ht} + \theta_q(y_{it}) q_{j(h)t} - \theta_p(y_{it})(p_{ht} + r_{j(h)t}) + \theta_d d_{iht} + \psi_{b(h)t} + \xi_{ht} + \varepsilon_{iht}, \quad (15)$$

[27]Relying on house prices makes our approach applicable to local infrastructure beyond drinking water, following a long tradition of estimating valuation for non-traded goods. Moreover, alternatives such as bottled water sales from consumer-panel scanner data cannot provide the fine-grained geographic and time variation and individual demographics we get from housing transactions.

[28]Relative to a hedonic approach inverting the equilibrium price surface, this allows us to recover preferences estimates that incorporate inframarginal house-buyers (Wong, 2018).

[29]Ideally, each boundary area lies within a single jurisdiction, allowing the fixed effect to capture factors such as school quality and neighborhood policies (e.g., zoning or crime prevention). Because this condition may not always be met in the data, as a robustness, we additionally control for school fixed effects and city/county government fixed effects, exploiting boundary areas that span multiple school districts or jurisdictions.

where $\theta_q(y_{it}) = \theta_{q0} + \theta_{qy}\log(y_{it})$ and $\theta_p(y_{it}) = \theta_{p0} + \theta_{py}\log(y_{it})$ allow sensitivities to water quality and housing costs—the sum of house price and water rate—to vary with buyer income. The idiosyncratic taste shocks ε_{iht} are assumed to follow the Type I extreme value distribution.

Given the demand specification in equation (15), we define resident i's marginal willingness to pay for quality, which varies with income y_{it}, as

$$\omega(y_{it}) = \frac{\theta_q(y_{it})}{\theta_p(y_{it})}.$$

This ratio converts the utility gain from water quality improvements into dollar units, representing resident i's willingness to pay for a marginal increase in water quality.

Estimation of the house demand parameters in equation (15) then proceeds in two stages, following Bayer et al. (2007). In a first step, we estimate the house-specific utilities, denoted by δ_{ht}, along with the non-linear parameters governing buyer heterogeneity, via maximum likelihood. The estimation sample includes every residential property sold in California between 2002 and 2019. To minimize arbitrary restrictions on potential buyers' choice sets, we consider large geographic markets, as shown in Appendix Figure D3. Appendix D provides details on the computational approach adopted to estimate demand with a large number of products per market.

Our second step recovers the parameters governing residents' average willingness-to-pay by regressing the estimated mean utilities δ_{ht} on house characteristics, prices, and water quality. Due to the endogeneity of house prices, we instrument for prices using a variant of BLP instruments (Berry et al., 1995).[30] Note that we allow residents preferences to only depend on the current level of water quality and rates. Therefore, we abstract away from residents dynamic considerations, as our estimates capture flow willingness to pay for current water quality levels. As shown by Bishop and Murphy (2019), if pollution is mean-reverting, as would be expected if severe pollution triggered abatement measures, our estimates would then be biased downward, thus leading us to understate the welfare gains from drinking water quality improvements.

[30]Specifically, we capture the influence of nearby houses while excluding those in close proximity, exploiting variation in the exogenous characteristics of alternatives without picking up unobserved local amenities that are shared within small geographic areas. We provide additional details in Appendix D.

6.5. **Estimation of the policymaker's cost and wedge.** Identification of the flow payoff difference associated with investment follows standard arguments in the dynamic discrete choice literature (Rust, 1987; Hotz and Miller, 1993).[31]

We then separately identify the payoff parameters λ_j and κ_j using the following sources of variation in the data. The wedge λ_j is identified from variation in residents' aggregate net value of investment that shifts the political payoff from investment while leaving the policymaker's private implementation cost unchanged. Specifically, the responsiveness of investment to these changes in residents' net value of investment pins down λ_j. In contrast, κ_j is identified from residual variation in investment decisions after accounting for these welfare shifts and the responsiveness of policymakers captured by λ_j.

To generate variation in electorates' net value of investment—the component of resident welfare that enters the policymaker's political payoff—we exploit changes in the underlying cost of investment and water quality. The latter evolve over time due to fluctuations in environmental conditions affecting pollution levels, while it can also depend on time-invariant factors like the water source. The former vary depending on the likelihood of obtaining federal subsidies. Policymakers observe these state variables and anticipate their implications for residents' welfare when making investment decisions.

We treat the policymakers' payoff parameters, κ_j and λ_j as functions of persistent jurisdiction-specific institutional features that do not respond to short-run demographic or pollution fluctuations. To discipline the welfare weight λ, we construct an index of electoral accountability for each jurisdiction, denoted by A_j, and assume

$$\lambda_j = \exp(\theta_{\lambda 0} + \theta_{\lambda 1} A_j)\,.$$

Our baseline accountability measure is derived from the frequency of contested elections, the key factor disciplining the policymaker's actions.[32]. Namely, we predict the probability of a contested election based on a Probit model with jurisdiction and year fixed effects and an interaction between an even-year indicator and an indicator for

[31]Note that we set $\beta = 0.92$, as the discount factor is not identified from choice-state data without additional restrictions (Rust, 1987; Magnac and Thesmar, 2002). Moreover, we assume that the policymaker has rational expectations about the endogenous state variables (l^q, l^r) , where beliefs about future states are identified from observed transitions in water quality and rates, as discussed above. For tractability, although this could be relaxed, we assume that the policymakers do not anticipate future changes in exogenous state variables.

[32]As a robustness check, we also construct a composite measure that incorporates both the frequency of contested elections and the presence of local newspapers.

jurisdictions with even-year elections. Our measure of electoral accountability, A_j is the average predicted probability of a contested election over two-year intervals for each jurisdiction j.[33] With this measure of electoral accountability we aim to capture exogenous jurisdictional characteristics arising from entrenched, slow-moving institutional features—such as election cycles and government structure—and therefore not subject to rapid changes.

To account for alternative factors influencing a jurisdiction's investment capabilities, we specify the private investment cost κ_j to reflect its administrative capacity to plan and implement capital projects. Specifically, we model κ_j as a linear function of the log number of employees dedicated to water-utility operations (averaged across the period of our study) and a binary indicator for small systems serving fewer than 10,000 residents.

Given these specifications, the policymaker payoff parameters are then estimated by maximum likelihood, solving the dynamic program at each parameter guess with a nested fixed-point algorithm (Rust, 1987).

7. Estimation results

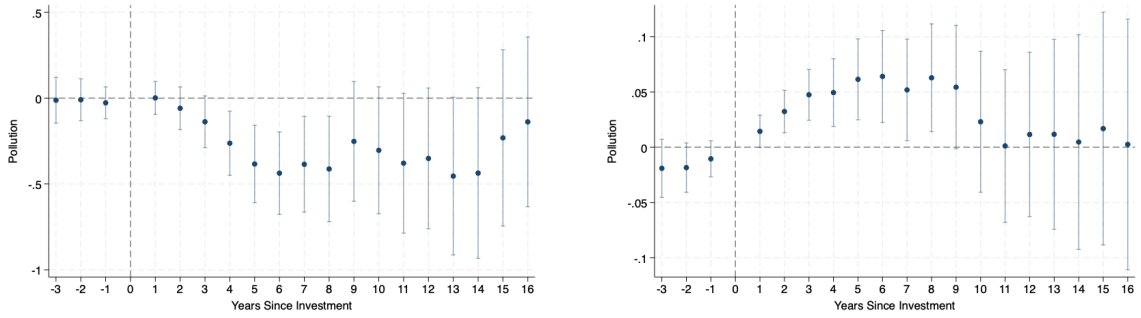
This section reports the model estimates. We begin by the estimated water quality and cost dynamics, highlighting the effectiveness capital investments in drinking water infrastructure and the heterogeneous costs borne by residents. We then turn to residents' preferences, summarized by their marginal willingness to pay for quality, $\omega(y)$. Together, these estimates allow us to assess distortions in investment decisions without relying on the policymaker parameters. We then present estimates of the policymaker's capacity cost in planning and undertaking an investment and their responsiveness to resident welfare.

7.1. Effectiveness and cost of investments.

Panel (A) of Figure 2 plots the event-study coefficients from (12). Relative to the pre-investment baseline, water-system upgrades produce a sharp and statistically significant decline in contamination: in

[33] In the model, λ_{jt} is in principle allowed to depend on a vector of jurisdictional characteristics, $\boldsymbol{x}_{jt}$. In practice, however, identifying a flexible mapping from $\boldsymbol{x_{jt}}$ to λ_{jt} is challenging because it requires sufficient independent variation in the welfare gains from investment across jurisdictions and over time. Much like estimating heterogeneous slope coefficients in a reduced-form regression, a richly parameterized specification would demand substantially more variation than is available in the data. We therefore summarize relevant institutional heterogeneity using the index A_j and parameterize λ_j as a function of this scalar measure.

FIGURE 2. Effects of Investment on Water Pollution and Rate



(A) Water pollution (B) Water rate

Notes: The figure displays the estimated coefficients for the dynamic effects of local government drinking water infrastructure investments on water pollution (Panel A) and average per-household water rates (Panel B), using data over the period 2003-2022. Water pollution is measured as the share of pollutants with readings that exceed the federal maximum contaminant level, including EPA health violations as a separate, additional pollutant.

TABLE 3. Heterogeneous Effects of Investment on Water Rate

	Low Borrowing	High Borrowing
Investment Effect	0.016	0.093
	(0.026)	(0.038)

Notes: This table reports the average post-treatment effects on water rates during the first five years following a drinking-water infrastructure investment, separately for jurisdictions with high and low levels of investment size, net of federal or state subsidy support. Standard errors are clustered at the jurisdiction level. The sample covers 2003–2022.

years 3-8 after installation the log pollution index falls by about 0.27, a 27% reduction in drinking water pollution either the EPA violations or contaminant readings above the MCL. This magnitude closely matches the 0.5 pp drop (roughly 33 %) reported by Keiser et al. (2023) for systems receiving Drinking Water State Revolving Fund loans. Appendix E shows that the effect is fairly uniform across systems with different observable characteristics. Notably, the improvement erodes over time and has vanished in sixteen years. This maps to $\delta^q = 0.878$ and $\tau^q = 1.364$.

Table 3 presents the event-study estimates from (14). Relative to the pre-investment baseline, locally financed upgrades lead to a statistically significant increase in water rates of about 5%, which persists for roughly nine years following the investment.

Reflecting the substantial heterogeneity in financing terms (Appendix Figure E8), our model allows the rate impact of investment to depend on the predicted investment amount per household, *net of state and federal grants*. The results in the table show that rate increases are driven almost entirely by the jurisdictions that rely heavily on borrowing to finance drinking-water infrastructure instead of federal and state subsidies ("High Borrowing"). Jurisdictions below the median borrowing level experience virtually no change in water rates, whereas those above the median see an average increase of about 9%.

7.2. **Resident preferences for drinking water quality.** Table 4 presents the demand estimates specified in (15), obtained using the two-stage procedure of Bayer et al. (2007). We estimate two specifications, with and without allowing preferences for neighborhood income composition that vary with household income. The results are similar across specifications. As expected, the coefficient on commuting distance θ_d and the coefficient on the composite annualized housing cost (including the water rates) θ_{p0} are both negative: residents prefer shorter commutes and lower housing costs. In addition, the estimates on house characteristics also have the expected signs: residents value larger lots, houses with more bedrooms, and neighborhoods with a higher share of college graduates.

Finally, we estimate a negative, and significant, coefficient on water pollution, implying that residents do value cleaner drinking water. Our estimates imply that high-income buyers are not as pollution-sensitive as low-income residents, suggesting that they can compensate for higher pollution by reducing their exposure through expensive equipment like filtration systems. In line with the existing literature (Bayer et al., 2007, 2016), we also find that higher-income buyers are less price sensitive. Taken together, the two competing forces imply that higher-income residents display a lower marginal willingness to pay for water quality than lower-income residents.

In Appendix D.2, we provide additional results that confirm that house prices are responsive to water pollution. First, we show hedonic regressions that show that residents dislike water pollution, including school and city fixed effects to limit variation coming from differences in jurisdictions besides water systems. Second, to ensure our results don't reflect unobserved amenity differences across boundaries, in Appendix D.2 we also present an event study of house prices after an health-based drinking water violation. We find that house prices within a jurisdiction's boundary

TABLE 4. Residents Value Drinking Water Quality Heterogeneously

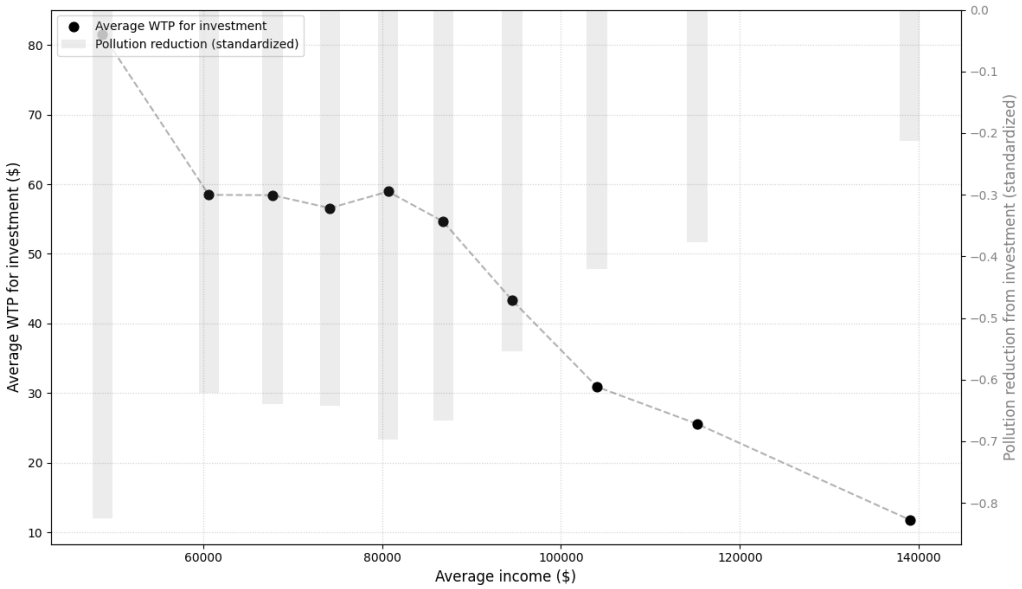
	Without Neigh. Pref. (1)	With Neigh. Pref. (2)
First Stage		
Income (log) × Water pollution	0.008 (0.550)	0.025 (0.115)
Income (log) × House price	36.241 (0.044)	32.116 (0.118)
Distance to workplace	-6.792 (0.040)	-6.799 (0.273)
Income (log) × Block-group income		0.480 (0.236)
Second Stage (IV) - Dep. Var: $\hat{\delta}$		
House user cost (price + rate)	-66.187 (1.257)	-59.742 (1.116)
Water pollution	-0.020 (0.007)	-0.023 (0.009)
Fraction of white	0.003 (0.000)	0.002 (0.000)
Fraction of college educated	0.968 (0.047)	0.933 (0.046)
# Bedrooms (log)	0.037 (0.007)	0.038 (0.006)
Sq. Footage (log)	1.066 (0.030)	0.971 (0.027)
Other house attributes	Yes	Yes
Border × Year FE, Market FE	Yes	Yes
Observations	870,637	870,637

Notes: This table presents the demand estimation results from the two-stage procedure of Bayer et al. (2007). Standard errors are in parentheses. The specification in column (2) allows preferences for neighborhood income composition to vary with household income by including an interaction between household income and block-group income.

fall significantly in the three years following the violation, suggesting that water quality is an important amenity valued by residents.

Figure 3 shows willingness to pay for drinking water investment across household income groups as the product of two components. The first is households' willingness to pay for pollution reduction, recovered from our demand estimates in Table 4. These estimates imply a median willingness to pay of $66 for a one-standard-deviation reduction in pollution. The second is investment effectiveness, estimated in Figure 2: we find that investment reduces pollution by 27%, with little detectable heterogeneity across systems. Because lower-income households tend to reside in more polluted jurisdictions, the pollution reduction induced by investment is larger for them, as shown by the gray bars in Figure 3. Combining these estimates therefore implies that willingness to pay for drinking water infrastructure investment declines with income, as shown in the black dots in Figure 3. Following the identification strategy outlined in Section 6.5, the heterogeneity illustrated in Figure 3 provides the key variation that we leverage to recover how local political factors shape infrastructure investment.

FIGURE 3. Households Willingness to Pay for Drinking Water Infrastructure Investment



Notes: This figure shows average willingness to pay for investment across income bins, computed as the product of two terms: $wtp^{INV}(y) = \omega(y) \times \Delta q(y)$. Here, $\omega(y)$ captures heterogeneity in willingness to pay for pollution reduction by household income y, and $\Delta q(y)$ denotes the average reduction in pollution associated with investment in the jurisdictions where households with income y live. The dashed line and black dots, read against the left axis, plot $wtp^{INV}(y)$ in CPI-adjusted 2020 dollars. The gray bars, read against the right axis, show $\Delta q(y)$, measured in standard deviations of pollution across jurisdiction-years.

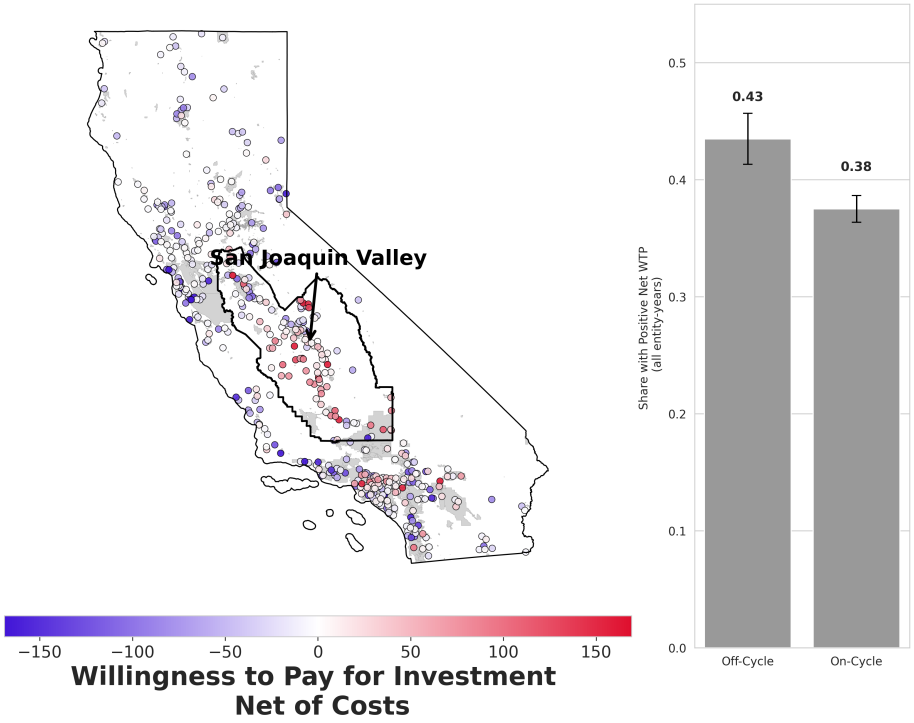
7.3. **Quantifying the net benefits of investment.** Taken together, our estimates for residents' preferences and investment costs can be used to quantify the value of investment in clean water infrastructure to residents. To this end, we compute the net change in the residents' utility $u(q_t, r_t; y_{it})$ following an investment in drinking water infrastructure:

$$\Delta u(q_t, r_t; y_{it}) = \omega(y_{it})\Delta q_t - \Delta r_t, \tag{16}$$

where the changes Δr_t and Δq_t are quantified from the estimates in Section 7.1, and $\omega(y_{it})$ estimated in Section 7.2.

Figure 4 depicts the average net benefit of investment across utilities in our sample. We find that for 39% of utilities serving in total 65% of the population, residents would benefit from investment. Among these utilities, the average net benefit is $42

FIGURE 4. Net Benefits of Investment across Space and Election Timing



Notes: On the left panel, the figure displays the net investment benefits in 2020 USD as defined in equation (16) averaged across residents served by a community water system, represented by each polygon. On the right panel, the bar graph presents the fraction of cities whose total net benefit of an investment is positive, for the two groups of cities depending on their mayoral and city council election schedule coinciding with the Election Days or the Presidential or state-wide primary dates ("on-cycle" vs. "off-cycle").

per year per household, and the benefits from investment are, on average, 4.5 times higher than the cost.

These results suggest that there is under-investment in water infrastructure for a sizable portion of the population in our sample. Can the lack of political accountability partially explain the under-investment in drinking water infrastructure? To answer this question, Figure 4 showcases the share of utilities for which we estimate positive net returns from investment, separately for utilities that hold on-cycle elections those that do not. Under-investment is more prevalent in off-cycle utilities: 43% of these utilities would benefit from investment, about 5 percentage points higher than the corresponding share among on-cycle utilities. This result is consistent with the idea that lower electoral accountability in "off-cycle" cities creates a wedge between the

TABLE 5. Estimates of the Role of Political Factors in Investment

	Coefficient	Std. Error
κ: Capacity		
Constant	3.276	(0.371)
Number of skilled employees (log)	-0.157	(0.028)
Small-sized	0.454	(0.039)
λ: Weight for constituent welfare		
Constant	-15.874	(3.160)
Electoral accountability index	9.613	(3.349)
County FE	Yes	
Observations	8,986	
Avg. Neg. log-likelihood	0.230	

Notes: This table presents coefficient estimates for the parameters governing the role of local institutional and political factors. Coefficients are estimated using Nested Fixed Point (NFXP) maximum likelihood and standard errors are computed using the approximate Hessian at the parameter estimates. The estimation sample focuses on the 80% of entities with the largest average expected pollution, so that investment is more plausibly related to pollution abatement. The specification for κ is linear in the jurisdiction attributes, and the specification for λ is log-linear in a constant and an accountability measure based on the jurisdiction-specific frequency of contested elections during the period of study.

local politician's investment decisions and its constituents' needs, leading to higher under-investment.

7.4. **How local political factors shape infrastructure investment.** Table 5 presents the estimated parameters governing political constraints in the model. Consistent with the evidence in Section 4, our estimates reveal that when electoral accountability is higher, local officials are more responsive to their constituents welfare. As a result, we show in Appendix Figure F9 that our estimated model fits two important patterns from the data well: observed investment probability falls when predicted investment costs rise and increases with predicted pollution. Turning to capacity parameters, we find notably that the private cost of investments κ_j is higher for small systems and decreases with the number of highly paid employees working at the water system. Ignoring the effect that changing private costs would have on continuation values, increasing the skilled workforce at a water system by 10% would increase the log-odds of investment by about 1.6%. This result echoes recent findings

on the role of skilled employees in shaping the ability of local governments to invest in infrastructure (Liscow et al., 2025).[34]

8. Quantification and policy implications of accountability

We use our estimated model to quantify the role of local electoral accountability in shaping drinking infrastructure investments. We consider a counterfactual where our accountability index is set equal to its highest level in the sample.[35,36] We first simulate the resulting investment paths and their implications for water pollution and rates. Next, we evaluate how the effects of existing federal and state subsidies on drinking water quality would differ under this higher electoral accountability scenario.

8.1. **Impact of accountability on infrastructure investment.**

Under the high-accountability counterfactual, we hold the generosity of drinking water subsidies constant and fix the impact of investment on water rates to our event study estimates (Figure 2), and we solve for the revised optimal investment decisions of local officials across the state space.[37] As we describe below, overall, our results showcase that greater electoral accountability increases investment in the systems that need it most.

Panel (A) of Figure 5 plots average investment probability under both the observed baseline and the high-accountability counterfactual, split by quintiles of underlying system pollution. We define underlying pollution as $\frac{1}{T}\sum_t \alpha_{jt}$ from the estimated pollution law of motion. Under the high-accountability counterfactual, investment is reallocated toward jurisdictions with the greatest need and modestly reduced in cleaner jurisdictions relative to the baseline.[38] In the most pollution-prone systems

[34]Many of primary state and federal funding sources are restricted for capital improvements, and cannot be used to alleviate insufficient capacity due to the limited availability of skilled employees, as noted by this 2020 report from the California Legislative Analyst Office.

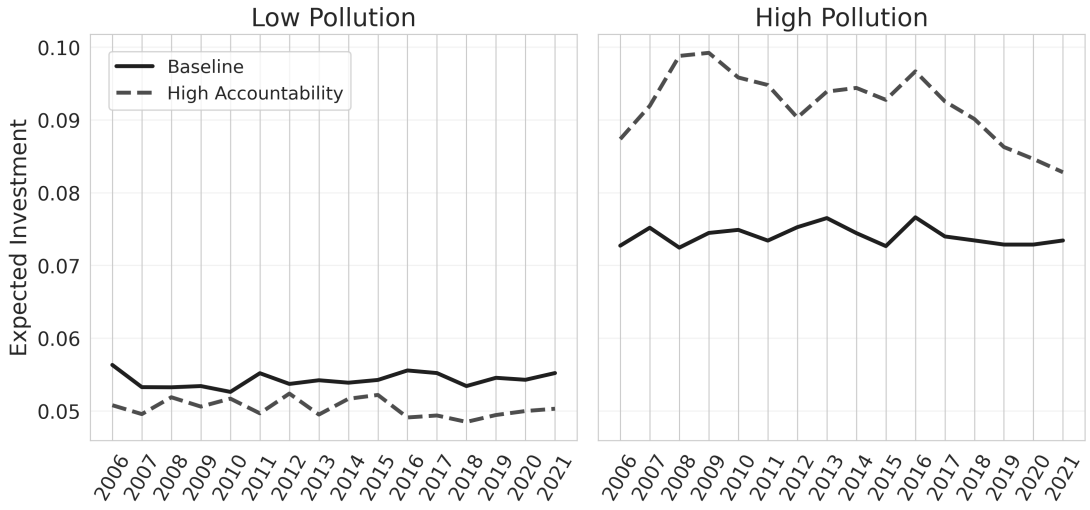
[35]Given our definition of the index, this corresponds to the case where governments face consistently contested elections throughout the sample period.

[36]Although such an increase in accountability may appear ambitious, recent policy changes illustrate that shifts in electoral competitiveness are feasible. For example, California Senate Bill 415 (the California Voter Participation Rights Act) induced many jurisdictions to move from off-cycle to on-cycle elections, which increased election contestedness (Table C4 in the Appendix C). This episode provides a concrete policy precedent for changes that enhance local electoral accountability.

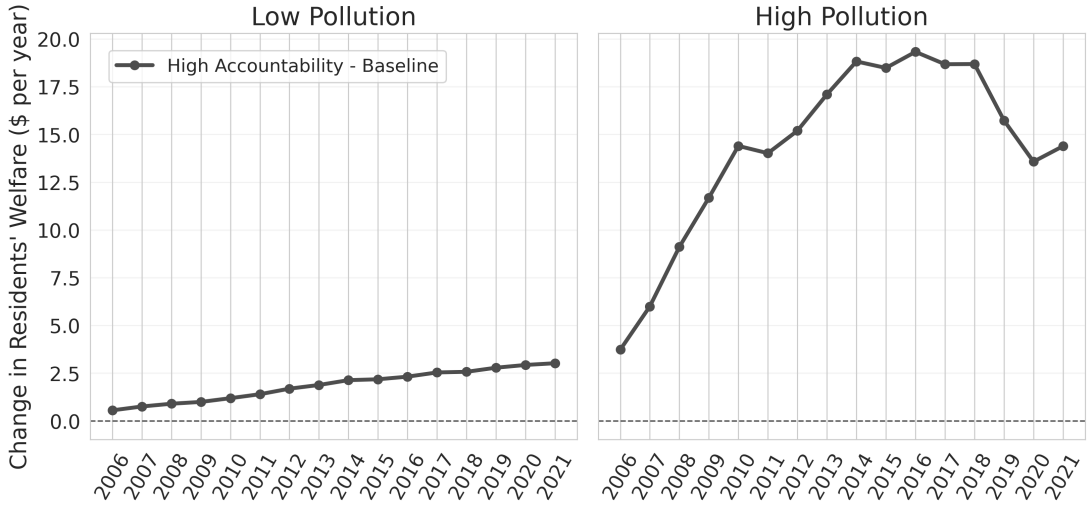
[37]Specifically, we initialize every system to their observed state in 2003 and simulate 1,000 paths of investment, pollution, and water rates until the end of our estimation period, 2022.

[38]This pattern closely aligns infrastructure decisions with the stated objectives of state and federal drinking water programs. See, for example, the California DWSRF Intended Use Plan, which notes that "The DWSRF program finances infrastructure improvements to mitigate drinking water risks and support the human right to water."

FIGURE 5. Role of Electoral Accountability



(A) Investment



(B) Resident welfare

Notes: Panel (A) plots the average investment probability under the counterfactual scenario in which the accountability index A_j is set equal to its highest level for all jurisdictions. The investment probability is averaged across simulated paths and across governments grouped by quintiles of average expected pollution. For each government j, average expected pollution is defined as the sample mean of α_{jt} in (13). The "Low pollution" group comprises governments with the lowest expected pollution, while "High pollution" comprises those with the highest. The solid line ("Baseline") shows observed investment probabilities, and the dashed line ("High Accountability") shows the simulated probabilities under the counterfactual. Panel (B) reports the average change in resident welfare under the counterfactual, averaged across simulated paths and governments.

(right panel), investment probability rises by over 2 percentage point from a 7% baseline - an increase exceeding 25%. Given the estimated effectiveness of investment (Section 6), this translates into substantial pollution reductions of up to 0.35 standard deviations. By contrast, accountability modestly reduces investment in the least pollution-prone systems, where the marginal benefits of further pollution reduction fail to outweigh the associated increases in water rates.

Panel (B) of Figure 5 plots the resulting change in constituent welfare, which weighs their willingness to pay for improved water quality against the higher water rates required to finance investment. By increasing λ_s, greater electoral accountability aligns government decisions more closely with constituents preferences, and therefore generates welfare gains. The magnitude of these gains is economically meaningful: in the most polluted systems, average household welfare increases as high as $20 per year, exceeding the median per-household cost of investment (approximately $18.5). These estimates likely understate the true welfare effects of accountability. As discussed in Section 6, our preference parameter estimates may be conservative with respect to the health and economic costs of drinking water contamination.[39]

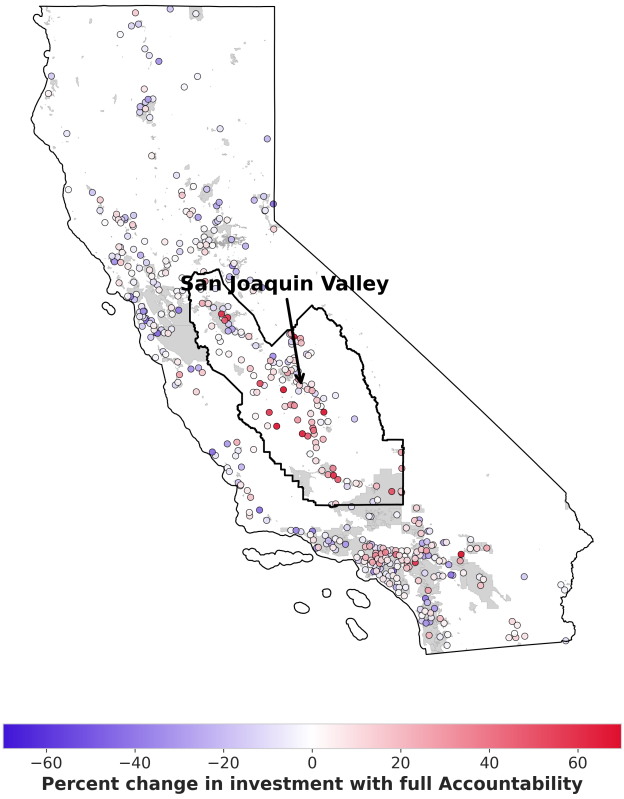
In addition to increasing the efficiency of infrastructure investment, greater electoral accountability has progressive distributional consequences. Figure 6(A) shows the spatial distribution of investment changes from increasing accountability across California. Large increases in investments are concentrated in the San Joaquin Valley, an agricultural region in Central California facing persistent water quality issues (Balazs et al., 2011, 2012). Many of these jurisdictions also suffer from weak electoral competition at the local level.[40] As such, even when funding is available, the incentives for local officials in those water boards to address pressing pollution issues may not be strong.[41] Consistent with this pattern, Figure 6(B) shows that accountability-induced investment increases are larger in more disadvantaged communities. Investment increases more in systems with lower share of college educated residents, higher shares of Hispanic residents, lower homeownership rates, and lower median household income. Thus, with greater accountability, investment patterns

[39]For example, Keiser et al. (2023) report that DWSRF loans and grants reduce mortality among older adults, and Hill and Ma (2022) documents adverse impacts of fracking-induced water pollution on infant health.

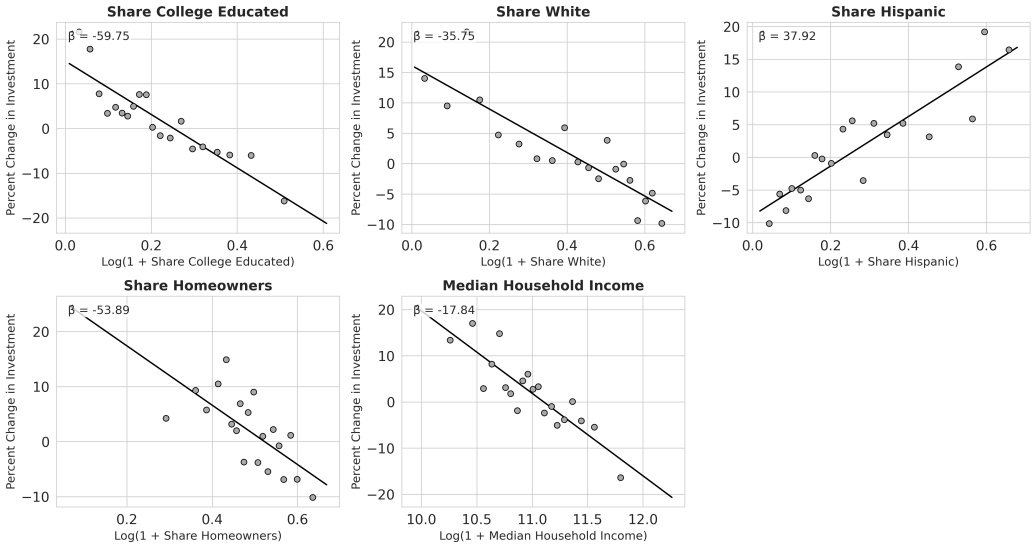
[40]A 2018 report by the non-profit Community Water Center notes that "In the local water boards of the southern San Joaquin Valley, contested elections are the exception, not the rule."

[41]Anecdotally, East Orosi CSD in the San Joaquin Valley accumulated 99 water quality violations over our sample period without undertaking any investment or holding a contested election; the system was placed under a state administrative order in 2022.

FIGURE 6. Heterogeneous Effects of Accountability on Investment



(A) Across Space



(B) Across Demographics

would align more closely with state and federal policy objectives of improving water quality especially in small and disadvantaged communities.

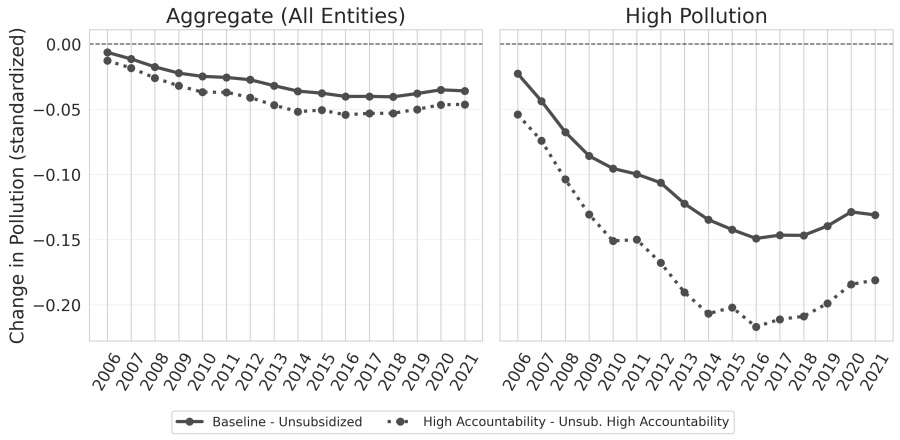
8.2. **Impact of accountability on the returns to public funding.** We next examine how limited political accountability affects the cost-effectiveness of federal and state funding programs for drinking water infrastructure, possibly undermining the targeting of these programs. Despite a range of federal and state financing initiatives (Section 2.4), funds may not necessarily flow to the jurisdictions that need them most (Hansen et al., 2021). First, we compute the counterfactual water rate increases that would be needed to fund infrastructure investment in the absence of external subsidies.[42] Then, using our estimated model, we solve for the revised optimal investment decisions of local officials across the state space, under both the high-accountability environment, and the observed one.

Figure 7(A) shows that current federal and state subsidies decrease pollution by around 0.028 standard deviations on average and up to 0.105 standard deviations for the highly polluted areas. The decrease would be 37% larger on average in the high-accountability scenario, and 47% larger for the most polluted systems. Figure 7(B) illustrates the mechanism by plotting subsidy take-up—measured in dollars per resident—against the (gross) welfare gains from investment in both scenarios. In the baseline, subsidy take-up is relatively higher when welfare gains are low and relatively lower when welfare gains are high, compared to the high-accountability benchmark. This pattern reflects a wedge created by limited accountability between politicians' investment decisions and residents' welfare gains, leading to a misallocation of subsidies toward investments that are less effective at reducing pollution.

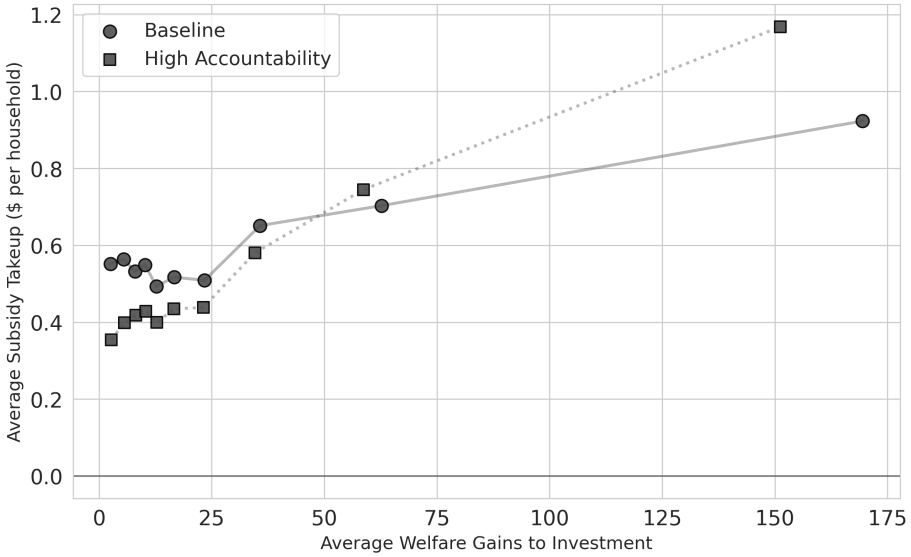
These results imply that alleviating fiscal constraints alone may not ensure efficient decentralized infrastructure provision. When local accountability is limited, subsidies may fail to flow to the highest-return projects. Our findings therefore call for approaches to local infrastructure funding that strengthen accountability or mitigate local discretionary distortions, for example through administrative oversight or institutional support that helps local governments to identify, plan and access central government funding opportunities.

[42]See the detailed construction of the no-subsidy water rate increases in the Appendix.

FIGURE 7. Effects of Infrastructure Subsidies by Accountability



(A) Impact on pollution



(B) Subsidy take-up by welfare benefits

Notes: Panel (A) shows the effect of federal and state subsidies on drinking water pollution under both the baseline and the high-accountability scenarios, while holding the subsidy environment constant. "Baseline - Unsubsidized" (solid line) indicates that subsidy effectiveness is simulated at observed levels of electoral accountability. "High Accountability - Unsub. High Accountability" (dashed line) indicates a simulation under a scenario where every election has at least two contenders, so that our accountability index A_j is set to be equal to its highest level in the sample. Panel (B) shows the average subsidy take-up per household in 2020 USD as a function of the "gross" welfare gains from investment, that is, the welfare benefits that would accrue to residents only from pollution decreases, ignoring associated water rate increases, expressed in 2020 USD per household, per year.

9. Conclusion

We provide evidence that infrastructure investment decisions made by local governing bodies may not align with those that maximize constituent welfare. Using a novel data set on investment and performance of drinking water systems in California, we document that weaker electoral accountability is associated with worse pollution outcomes and lower take-up of state and federal subsidies. We then quantify the welfare consequences of higher pollution and water rates using a structural housing choice model, and measure the distortions generated by local political frictions using a dynamic investment framework. These frictions are costly: if all local elections were contested, with at least two candidates competing for every seat, investment would increase, pollution would fall, and welfare would improve, particularly in struggling systems serving disadvantaged communities.

More broadly, our findings highlight the role of political accountability in shaping allocative efficiency within decentralized public investment. Fiscal resources alone do not ensure efficient outcomes; the translation of transfers into welfare gains depends on the incentives faced by local policymakers to align their investment decisions with constituent welfare. Reforms that strengthen electoral accountability may therefore complement financial support by improving both the level and the targeting of investment. Designing infrastructure policy without accounting for political incentives risks limiting the impact of large-scale public spending. Thus, an important direction for future research is to examine which institutional reforms—such as electoral design, information provision, or oversight mechanisms—most effectively improve accountability, and how federal or state policy can be structured given the institutional constraints local governments face.

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Appendix A. Data Construction

A.1. **Construction of Investment Measures.** This section describes how we construct measures of drinking water infrastructure investment by combining multiple administrative data sources and classifying the purpose of each financing instrument.

A.1.1. *Data Sources and Investment Aggregation.* We collect information on government debt, loans, and subsidies used to finance water infrastructure investments from four sources: (i) outstanding debt records from California's Financial Transactions Reports (FTR), (ii) debt issuance records from the California Debt and Investment Advisory Commission (CDIAC), (iii) capital contributions from federal and state governments reported in water enterprise income statements in the FTR, and (iv) Drinking Water State Revolving Fund (DWSRF) loans and grants obtained through FOIA requests.

For each outstanding debt record in the FTR data, we observe the amount, issuance year, and a short description of the project purpose. We use this information to determine whether the debt corresponds to new financing or refinancing and whether it is related to drinking water infrastructure.[1] We combine these records with CDIAC data to improve coverage and measurement, as CDIAC provides more detailed information on debt characteristics and issuance.

After identifying all relevant sources of financing—including bonds, federal and state loans, DWSRF loans and grants, and direct subsidies—we compute the total amount of new funding raised for water infrastructure investment in each jurisdiction-year. Because investment financing may occur over multiple consecutive years, we group contiguous years with positive financing into an "investment spell." We assign the first year of each spell as the investment year and sum total financing over the spell as the investment amount. Finally, we define an investment indicator equal to one if the total investment amount exceeds $500,000 (in 2020 dollars) in that spell.

A.1.2. *Classification of Investment Purpose.* A key challenge in constructing investment measures is distinguishing drinking water infrastructure from other types of public investment. We classify municipal debt records into three categories based on the stated purpose of the debt and, when available, the nature of the pledged revenue: drinking water infrastructure, wastewater or sewer infrastructure, and unrelated projects. Drinking water infrastructure includes projects related to water

[1]We exclude refinancing activities from our investment measure.

supply, treatment, distribution, storage, contamination mitigation, and capital improvements supporting potable water systems. Wastewater or sewer infrastructure includes projects related to wastewater, sewer, sludge, or effluent systems. All other projects—including public safety, transportation, solid waste, recreation, and general government expenditures—are classified as unrelated.

We assign each record to one of these categories using a keyword-based decision rule applied to project descriptions and revenue fields. Specifically, if the description or revenue field contains wastewater or sewer-related terms, the record is classified as wastewater infrastructure. If not, but the description contains keywords associated with unrelated projects, the record is classified as unrelated. If the description instead contains primary drinking water keywords—such as references to water supply, treatment technologies, storage, distribution, or contaminants—the record is classified as drinking water infrastructure. When the description contains only more general, secondary water-related terms (such as system improvements or construction), the record is classified as drinking water infrastructure only if the pledged revenue field indicates a water-related funding source; otherwise, it is classified as unrelated. Records that do not meet any of these criteria are classified as unrelated.[2]

The keyword classification relies on predefined sets of terms, as follows:

- *Wastewater / Sewer Keywords:* WASTEWATER, WASTE WATER, SEWER, SEWERS, EFFLUENT, SLUDGE, WW
- *Exclusion Keywords:* POLICE, FIRE, LIGHT, STREET LIGHT, ANIMAL, DOG, ELECTRIC, POWER, VEHICLE, TRUCK, COPIER, PRINTER, MAIL, COMPUTER, SERVER, PENSION, AMBULANCE, DISPATCH, RADIO, CAR, FLEET, GARAGE, HOUSING, PARK, LIBRARY, AIRPORT, HARBOR, PORT, SOLID WASTE, TRASH, LANDFILL, CEMETERY, RECREATION, SPORT, PLAYGROUND, TENNIS, GOLF, MUSEUM, PHONE, POSTAGE, HONEYWELL, PUMPER, INFUSION PUMP, SOLIS PUMP, HOWELL, ENERGY, SEAWELL, FARM, CNG TANK, GAS TANK, BOAT, HUD, SECTION 108, MARINA, ECONOMIC DEVELOPMENT, LIFT STATION, MAIN BUILDING, DIGESTER, BIOSOLID, COMM DEV, COPY MACHINE, OFFICE
- *Primary Water Keywords:* WATER, DESAL, DESALINATION, TANK, WELL, GROUND WATER, SAFE DRINK, DRINK, DAM, PIPE, CHLORIN, FILTRAT, FILTER, PURIFY, PURIFICATION, METER, PUMP, RESERVOIR, MEMBRANE,

[2]For special districts, which are primarily water-focused entities, we do not distinguish between primary and secondary keywords and classify all water-related keywords as drinking water infrastructure.

ULTRAFILTRAT, OSMOSIS, DISINFECT, BACKWASH, CLEARWELL, BRINE, EQUALIZATION TANK, ARSENIC, LEAD, PFAS, PFOA, PFOS, NITRATE, NITRITE, MANGANESE, IRON, CONTAMIN, HEXAVALENT, CHROMIUM, MCL, BUREAU OF RECLAMATION, CENTRAL VALLEY PROJECT, DELTA, HYDROELECTRIC, SRF, DWSRF, STATE REVOLVING FUND, SWRCB, SCADA, CATHODIC, CORROSION, POTABLE, AWT, BASIN, ARROYO

- *Secondary Water Keywords:* SYSTEM, IMPROV, CAPITAL, FACILIT, CONSTRUCT, REMEDIAT, REMOV, ABAT, DISTRIBUT, INFRASTRUCT, INTAKE, BOOSTER, AERATION, TREAT, EXPAND, UPGRAD, REPLAC, EXPANS, CONNECT, PILOT, ACQUI, AUGMENT
- *Water Revenue Keywords:* WATER, NET WATER, WATER FEES, WATER REVENUE, WATER SYSTEM, WATER FUND, WATER CHARGES, WATER NET

In applying these rules, wastewater indicators take precedence over all other classifications, and exclusion keywords override any water-related keywords. Primary water keywords are sufficient to classify a project as drinking water infrastructure without requiring confirmation from the revenue field, whereas secondary keywords require such confirmation. Subsidy data, including DWSRF loans and grants and capital contributions reported in the FTR, are restricted to drinking water investments by construction and therefore do not require classification.

Together, these steps allow us to construct a consistent measure of jurisdiction-level drinking water infrastructure investment across multiple data sources and over time.

A.2. **Drinking Water Quality Data.**

A.2.1. *California Water Quality Analyses Data.* Our main source on drinking water pollution is the Water Quality Analyses data maintained by the California State Water Resources Control Board. We combine recent records from the Safe Drinking Water Information System (SDWIS, post-2011) with historical records from the Water Quality Management system (WQM, 1974–2010). Under the 1974 Safe Drinking Water Act (SDWA), the federal government sets drinking water standards, while states are responsible for monitoring public water systems, inspecting compliance, and maintaining records (Allaire et al., 2018). In California, public water systems collect samples at multiple stations and submit them to laboratories certified under the Environmental Laboratory Accreditation Program (ELAP). These ELAP-certified laboratories report test results directly to the California Division of Drinking Water (DDW), and these reports constitute our primary raw data.

Each record contains the sampled public water system, sample collection date, laboratory identifier, analyte name and code, test result, and reported unit of measurement. We undertake several harmonization steps across reporting systems and over time. We begin by restricting attention to contaminants that can generate health-based violations under the National Primary Drinking Water Regulations (NPDWR). For most such contaminants, the regulation specifies a maximum contaminant limit (MCL), usually expressed in milligrams per liter, though radionuclides are reported in picocuries per liter or millirems per year. One notable exception is fecal coliform, for which the rule is based on repeat-sample procedures rather than an MCL. Because California does not maintain electronic records of coliform samples, we exclude this contaminant from the analysis. We also exclude contaminants regulated through treatment techniques rather than MCLs, such as viruses and turbidity. After these restrictions, our analysis covers 74 federally regulated pollutants spanning four groups: inorganic chemicals, radionuclides, organic chemicals, and disinfection byproducts. Finally, as investments in our analysis could impact any part of the drinking water treatment cycle in a system, from water source to treatment plant, we keep all samples from every type of sampling station.

Many sampling records are reported as non-detects, indicating that the concentration falls below the detection limit of the sampling method. Following Keiser et al. (2023), we set these observations to zero. We then convert all readings into the units in which the relevant MCL is defined. Finally, again following Keiser et al. (2023), we aggregate the data to the system–pollutant level by computing the share of readings that exceed the corresponding MCL. To account for seasonal variation in contamination and differences in sampling schedules across systems, we also construct, for each system–pollutant pair, the fraction of readings collected in each month. As reported in Table A1 below, after this cleaning, the readings data comprises 74 pollutants. The median pollutant is sampled multiple times per entity, year. Broadly, the number of pollutants per chemical type, and the fraction of readings above maximum concentration limits are consistent with Keiser et al. (2023), except for disinfection byproducts where our data has a smaller share of readings exceeding the limit.

A.2.2. *Environmental Protection Agency Drinking Water Violations.* Our second source of data for drinking water pollutions are the drinking water violations from the SDWA "Violations and Enforcements" data set available online. This dataset records violations at the public water system level. Violations can be of different type, including

TABLE A1. Federally Regulated Contaminant Readings

Contaminant type	Number of readings	Number of pollutants	Share zero	% above MCL	Median readings pollutant-system-year
Inorganic Chemicals	1,880,703	16	0.538	4.42	3.0
Radionuclides	156,158	4	0.367	7.71	3.0
Disinfection Byproduct	1,569,156	4	0.631	0.35	16.0
Organic Chemicals	5,327,577	50	0.961	0.84	3.0

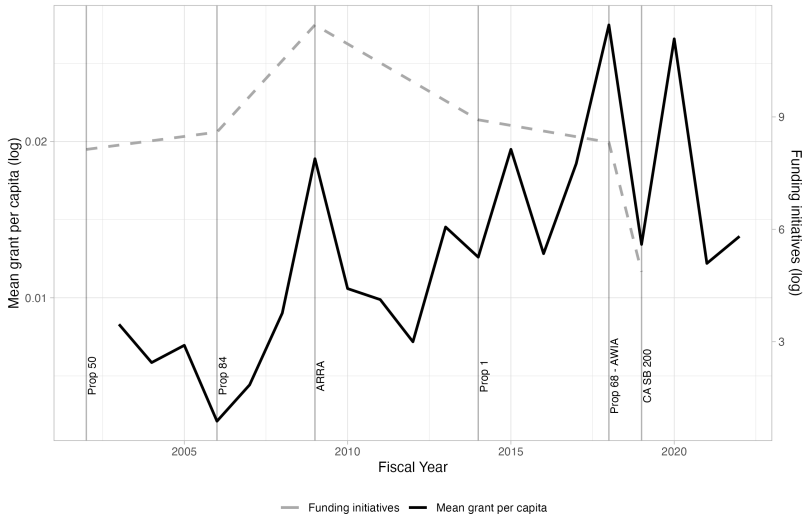
Notes: This table provides descriptive statistics of the contaminant readings data for public water systems matched to jurisdictions in our sample over the time period 2001-2023.

Monitoring, Reporting, and MCL violations. We focus on MCL violations only, ignoring other health-based violations such as Maximum Residual Disinfectant Level and Treatment Technique violations. Violations can be of different severity which translates into different public notification tiers, as specified by the Public Notification Rule (2000, revised in 2006). This rule ensures that the public is informed of drinking water violations posing potential risks to public health. The most serious category, Tier I, requires immediate notice within 24 hours after the public water system learns of the violation. Tier I public notifications might be issued via TV, radio, hand delivery, or any other method to reach all persons served by the public water system. Tier II requires public notification "as soon as practical" within 30 days, typically via mail. In addition, drinking water systems are required to issued annual consumer confidence reports (CCR) as per the 1998 CCR rule.

APPENDIX B. ELECTORAL ACCOUNTABILITY AND TAKE-UP OF STATE AND FEDERAL FUNDING

Figure B1 illustrates temporal variation in funding availability for drinking water infrastructure during our study period. The solid line plots the mean of grant amount per capita received by local governments in our sample, constructed from our administrative data combining California's Financial Transactions Reports (FTR), California Debt and Investment Advisory Commission (CDIAC) records, and EPA State Revolving Fund records acquired through FOIA requests. The dashed line summarizes major federal and state funding initiatives identified through our institutional review, including voter-approved bond measures and federal statutory funding expansions. The vertical lines mark the enactment years of these policies. While the two series are constructed from different sources, they exhibit similar time variation, with increases in grant funding following major legislative initiatives. These

FIGURE B1. Statutory Funding Shocks and Local Drinking Water Grants



Notes: This figure plots the mean grant amount per capita (solid line, left axis, log scale) received by local governments in our sample for drinking water infrastructure investment over the study period. The dashed line (right axis, log scale) indicates the total pledged funding amounts from major federal/state statutes and state general obligation bonds, including Proposition 50 (2002), Proposition 84 (2006), Proposition 1 (2014), and Proposition 68 (2018). Vertical lines mark the enactment years of these statutes.

patterns highlight substantial temporal fluctuations in funding opportunities faced by local governments, which we exploit to identify the responsiveness of infrastructure investment to exogenous changes in funding availability.

B.1. **Expected grant intensity.** Figure B1 illustrates the evolution of statutory funding initiatives for drinking water infrastructure in California. Over the sample period, several federal and state policies expanded the availability of grant funding, including the American Recovery and Reinvestment Act of 2009 and multiple state bond measures. Consistent with these policy changes, the amount of grant-funded investment per capita in our data increases over time as successive initiatives accumulate. Although the precise eligibility criteria and allocation rules for these programs are not fully observed, the timing of these legislative changes generates substantial temporal variation in funding availability.

To exploit this variation, we construct a measure of expected grant intensity that combines cross-sectional exposure to funding with time-series funding shocks. For each jurisdiction j in year t, we define an indicator for whether the jurisdiction

received grant funding,

$$h_{jt} = \mathbb{1}\{\text{Grant}_{jt} > 0\}.$$

While detailed allocation rules are not available, funding programs typically prioritize jurisdictions based on characteristics such as system size, income levels, and financial capacity. To capture systematic differences in exposure to these programs, we estimate a predicted probability of receiving funding, $\hat{h}_{jt} = f(\boldsymbol{x}_{jt})$, using a random forest model. The covariates $\boldsymbol{x}_{jt}$ include median household income; an indicator for income below program priority thresholds; an indicator for poor financial health; housing density; an indicator for small water systems; water source type; county; and year. We then define each jurisdiction's average exposure to funding as

$$p_j = \frac{1}{T} \sum_t \hat{h}_{jt}.$$

Next, we construct funding shocks based on realized grant allocations among demographically similar jurisdictions. Specifically, we form a donor pool $\mathcal{P}_j$ using k-means clustering on baseline (2003) characteristics–log population, log income, and log housing density. The median donor pool contains 33 jurisdictions. For each jurisdiction j, the funding shock in year t is defined as

$$g_{jt} = \exp\left(\frac{\sum_{k \in \mathcal{P}_j,\, k \neq j} \log(1 + \text{Grant Amt}_{kt})}{\sum_{k \in \mathcal{P}_j,\, k \neq j} 1} \right) - 1,$$

which captures contemporaneous funding variation among comparable jurisdictions while excluding jurisdiction j itself.

Finally, we combine exposure and funding shocks to construct the expected grant intensity measure used in the main text:

$$z_{jt} = p_j g_{jt}.$$

The resulting measure isolates variation in funding availability arising from aggregate policy-driven funding shocks while scaling it by each jurisdiction's predicted exposure to these programs.

We then investigate the extent to which variation in state and federal funding shifts investment. We show that increases in funding availability within entity lead to higher investment probability. Moreover, we show that this effect is muted for entities with weaker electoral accountability, defined as entities with a combination of infrequently contested elections and low local media presence. Our main result

TABLE B2. Do Governments Respond to Funding Opportunities for Investment?

	Dependent var.: Any investment			
	All		Low Accountability	High Accountability
	(1)	(2)	(3)	(4)
E(grant intensity)	0.3909***	0.4668***	0.0773	0.4644***
	(0.1415)	(0.1632)	(0.1626)	(0.1637)
E(grant intensity)× Higher accountability		-0.4876**		
		(0.2106)		
Jurisdiction FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	14,320	14,320	1,460	12,860
R^2	0.0602	0.0603	0.0589	0.0609

Notes: The dependent variable is an indicator for whether a jurisdiction undertakes any investment in a given year. E(grant intensity) is the expected grant intensity measure constructed as described in the text, combining cross-sectional exposure to funding programs with time-series funding shocks. Higher accountability is defined as jurisdictions with above-median election contestation and local media presence over the sample period; low accountability is defined analogously. Column (2) includes an interaction between expected grant intensity and an indicator for higher accountability. Columns (3) and (4) report estimates separately for low- and high-accountability jurisdictions. All specifications include jurisdiction and year fixed effects. Standard errors, reported in parentheses, are clustered at the jurisdiction level. Statistical significance is denoted by $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

corresponds to the following regression:

$$\mathbb{1}\{\text{Investment}\}_{et} = \phi_e + \mu_t + \beta z_{et} + \gamma z_{et} \times \mathbb{1}\{\text{Low Contested \& Low Media}\} + \epsilon_{et}$$

Table B2 presents results. Column (1) shows that higher expected grant intensity significantly increases the likelihood of investment, indicating that municipalities respond to changes in funding availability. Column (2) introduces an interaction with an indicator for low electoral accountability (jurisdictions with low election contestation and low media presence). The interaction term is negative and statistically significant, implying that the responsiveness to funding is substantially weaker in these environments. Columns (3) and (4) further illustrate this heterogeneity by splitting the sample. In low-accountability jurisdictions (column 3), the effect of expected grant intensity is small and statistically insignificant. In contrast, in high-accountability jurisdictions (column 4), the effect is large and statistically significant, comparable in magnitude to the baseline estimate. Overall, the results indicate that while increases in funding availability raise investment on average, this effect is concentrated in jurisdictions with stronger electoral accountability.

TABLE C3. Election Timing and Contested Elections

	Dependent var: Any contested elections			
	Full sample		Subsample	
	(1)	(2)	(3)	(4)
On-cycle election schedule	0.125***	0.117***	0.247***	0.235***
	(0.0326)	(0.0330)	(0.0474)	(0.0506)
Demographic attributes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
Jurisdiction FE	Yes	Yes	Yes	Yes
Observations	7,039	6,926	3,230	3,179
R^2	0.562	0.565	0.604	0.606

Notes. This table reports regression results where the dependent variable is an indicator for whether an election is contested. The unit of observation is jurisdiction × two-year period, reflecting that elections typically occur every two years. Standard errors clustered at the jurisdiction level are reported in parentheses. Statistical significance is indicated as follows: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Columns (1)–(2) use the full sample, while Columns (3)–(4) restrict the data to the post-2014 period and excludes jurisdictions that already had on-cycle election schedules prior to 2018, thereby exploiting variation from the implementation of the California Voter Participation Rights Act (SB 415, 2015). Controls include the logarithm of median household income, population, and population density; the shares of White and Hispanic residents and homeowners; and measures of precipitation levels and intensity.

APPENDIX C. EFFECTS OF ELECTION TIMING

Appendix Tables C3 and C4 provide additional evidence on how election timing affects electoral competition in our data. Table C3 examines whether elections are contested. Using jurisdiction × two-year observations with jurisdiction and year fixed effects, we find that elections held on-cycle—that is, aligned with statewide or federal contests—are substantially more likely to attract multiple candidates. Across specifications, moving to an on-cycle schedule increases the probability that an election is contested by roughly 12 to 25 percentage points. These patterns are robust to the inclusion of demographic controls and also hold in a subsample focusing on jurisdictions affected by the implementation of the California Voter Participation Rights Act (SB 415, 2015), which required some jurisdictions to move their elections on-cycle beginning in 2018.

Table C4 examines electoral competitiveness using incumbent vote margins. The dependent variable is defined as the minimum of zero and the incumbent vote margins averaged across elections within a jurisdiction × two-year period. We report results for both unbalanced and balanced samples. In the balanced specification, we

TABLE C4. Election Timing and Vote Margins

	Dependent var: Incumbents' vote margins			
	Unbalanced		Balanced	
	Full	Subsample	Full	Subsample
	(1)	(2)	(3)	(4)
On-cycle election schedule	0.00487	-0.0739	-0.0955*	-0.152**
	(0.0295)	(0.0573)	(0.0502)	(0.0687)
Demographic attributes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Jurisdiction FE	Yes	Yes	Yes	Yes
Observations	2,845	1,155	3,671	1,605
R^2	0.555	0.674	0.474	0.611

Notes. The dependent variable is $\min\{0, \text{incumbent vote margin, averaged across elections}\}$. The unit of observation is a jurisdiction $\times$ two-year period, reflecting that elections typically occur every two years. Standard errors clustered at the jurisdiction level are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Columns differ by sample definition. "Full" uses the entire sample. "Subsample" restricts the data to the post-2014 period and excludes jurisdictions that already had on-cycle election schedules prior to 2018, thereby exploiting variation from the implementation of the California Voter Participation Rights Act (SB 415, 2015). "Balanced" imputes an incumbent vote margin of 1 in uncontested elections when election information is available from the CEDA database, while "Unbalanced" does not perform this imputation. Controls include the logarithm of median household income, population, and population density; the shares of White and Hispanic residents and homeowners; and measures of precipitation levels and intensity.

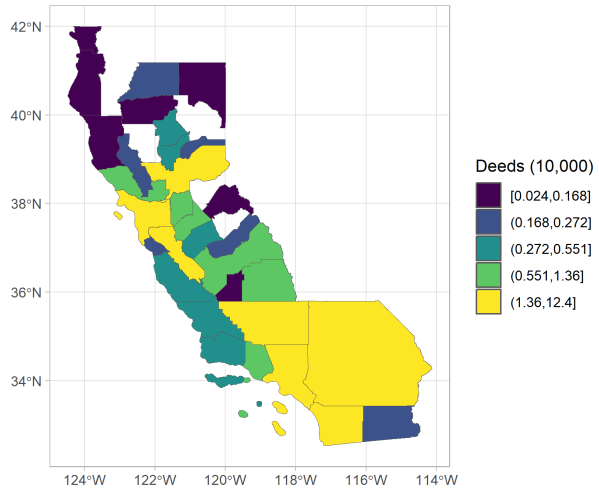
impute an incumbent vote margin of one in uncontested elections when election information is available from the CEDA database, while the unbalanced specification restricts attention to observed margins. Consistent with the results on contestation, the estimates indicate that on-cycle elections are associated with smaller incumbent vote margins, implying more competitive races. The magnitude of the effect is larger in the balanced panel, reflecting the incorporation of uncontested elections into the measure of electoral competitiveness.

APPENDIX D. DEMAND ESTIMATION

D.1. **Estimation approach.**

D.1.1. *Data construction.* We follow Bayer et al. (2016) and link the CoreLogic housing transaction (deed) dataset to individual mortgage applicant data made available by the Home Mortgage Disclosure Act (HMDA). This results in a dataset of severeal

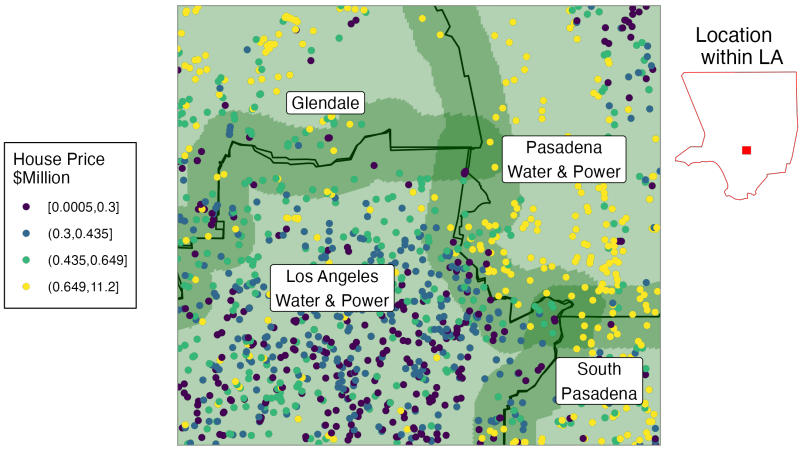
FIGURE D2. Geographic Markets used in Demand



millions house transactions between years 2003 and 2019 where we observe buyer income, ethnicity and race, and gender. In addition, we leverage the commuting matrix from the Longitudinal Household Employment Dynamics (LEHD) data to simulate a workplace for each house buyer based on the location of the house purchased. The simulated workplaces are therefore consistent with the empirical distribution of tract-to-tract commuting patterns in California in 2010. We then allocate these transactions to separate geographic housing markets defined using core-based statistical areas (CBSAs). Figure D3 below shows the resulting markets.

D.1.2. *Computational details.* As shown in Figure D3, the largest number of transactions in the geographic markets considered is above $100,000$. For the largest markets such as Los Angeles and the Bay Area, we define markets as geography–quarter instead of geography–year. This reduces the number of products but the largest market still consists in more than $30,000$ different transactions. As a result, we estimate our demand model using pytorch (Paszke, 2019). Our implementation follows the best practices Conlon and Gortmaker (2020), and we rely on pytorch for GPU acceleration and automatic differentiation. To efficiently apply automatic differentiation of the BLP contraction mapping, we follow the approach used in deep implicit layers models (see for instance, Bai et al. (2019)) and approximate the gradient by using an auxiliary fixed-point mapping that only requires the vector-Jacobian product which is directly provided by automatic differentiation libraries such as pytorch (Paszke, 2019). In doing so, we avoid both inverting a large $J \times J$ matrix and storing in

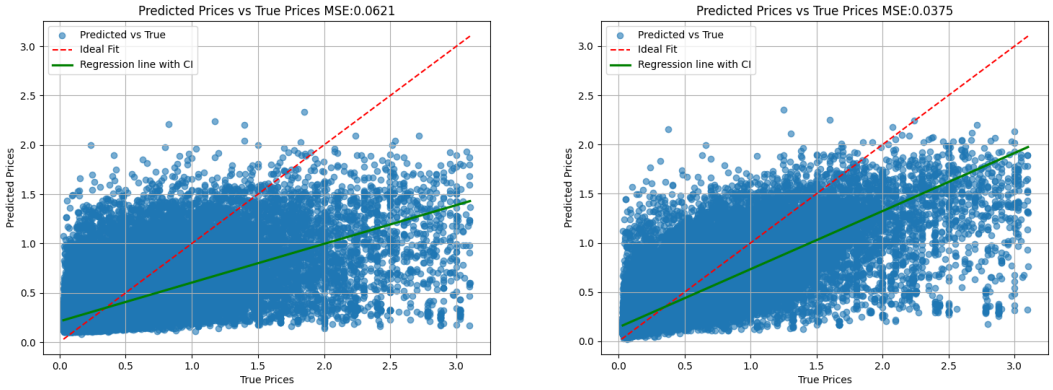
FIGURE D3. Boundary Discontinuity Design



memory all the intermediate tensors used to solve the contraction mapping at every parameter guess. With these changes, we use the L-BFGS optimization routine to estimate the parameters $\boldsymbol{\theta_2}$. We can estimate the demand model described in Section 6 in around five hours on a A100 GPU.

D.1.3. *Instrumental variable.* Following Bayer et al. (2007); Calder-Wang (2021) we intend to compute an instrument for prices using a guess of parameters and the model to construct the predicted house prices that result from variation in exogenous house characteristics only. To obtain an initial guess of the linear parameters $\boldsymbol{\theta_1}$, we need a preliminary instrument for house prices. We follow Gandhi and Houde (2019) and construct differences in exogenous house characteristics $\boldsymbol{x_h}$–number of bedrooms, bathrooms, building and land square footage, year built– where for a given characteristic ℓ we compute $z^1_{j\ell} = \sum_{k,1km\leq d_{hk}\leq 5km}(x_{j\ell} - x_{k\ell})$ and $z^2_{j\ell} = \sum_{k,1km\leq d_{hk}\leq 5km}(x_{j\ell} - x_{k\ell})^2$. Finally, we compute the best predictor of house prices, $\hat{p}_{jt} = \mathbb{E}[p_{jt}|\boldsymbol{x_{jt}}, \boldsymbol{z^1_{jt}}, \boldsymbol{z^2_{jt}}]$ using gradient boosted trees and cross-fitting. We show in Figure D4 that this instrument has a relevant first stage, and that information on houses around house j, excluding the ones directly in the vicinity of j, provides predictive power over and above the characteristics of house j itself.

FIGURE D4. Best Predictor of House Price



(A) $\mathbb{E}[p_{ht}|\boldsymbol{x_{ht}}]$ (B) $\mathbb{E}[p_{ht}|\boldsymbol{x_{ht}}, \boldsymbol{z^1_{ht}}, \boldsymbol{z^2_{ht}}]$

D.2. **Additional hedonic regression results.** In addition to the structural demand model presented in the main text, we also estimate the following hedonic regression:

$$\log(p_{ht} + r_{ht}) = \beta q_{ht} + \gamma \boldsymbol{x}_{ht} + \psi_{b(h)t} + \rho_s + \mu_g + \epsilon_{ht}, \tag{17}$$

where q_{ht} corresponds to different measures of water quality and where we control for house characteristics and neighborhood demographics, represented by $\boldsymbol{x}_{ht}$. To account for time-varying unobserved neighborhood attributes that influence house prices, we include boundary-year fixed effects, $\psi_{b(h)t}$, which equals one if house h is located within 500m distance of a PWS service area boundary b in year t, $\psi_{b(h)t}$. Ideally, each boundary area lies within a single jurisdiction, allowing $\psi_{b(h)t}$ to capture factors such as school quality and local policies (e.g., zoning or crime prevention). However, since this condition might not always be met in the data, we include boundary areas that span multiple school districts or jurisdictions. For this reason, we additionally control for school fixed effects and city/county government fixed effects.

Columns (1) and (2) of Table D5 show that water pollution, as measured by the average percentage by which contamination exceeds the federal standards across all pollutants during the calendar year of the sale, significantly impacts house prices. Across the specifications, a one standard deviation increase in water pollution is associated with a 1.4-1.6% decline in house prices. This magnitude aligns with the estimated effects of ozone pollution on house prices reported by Bayer et al. (2016).

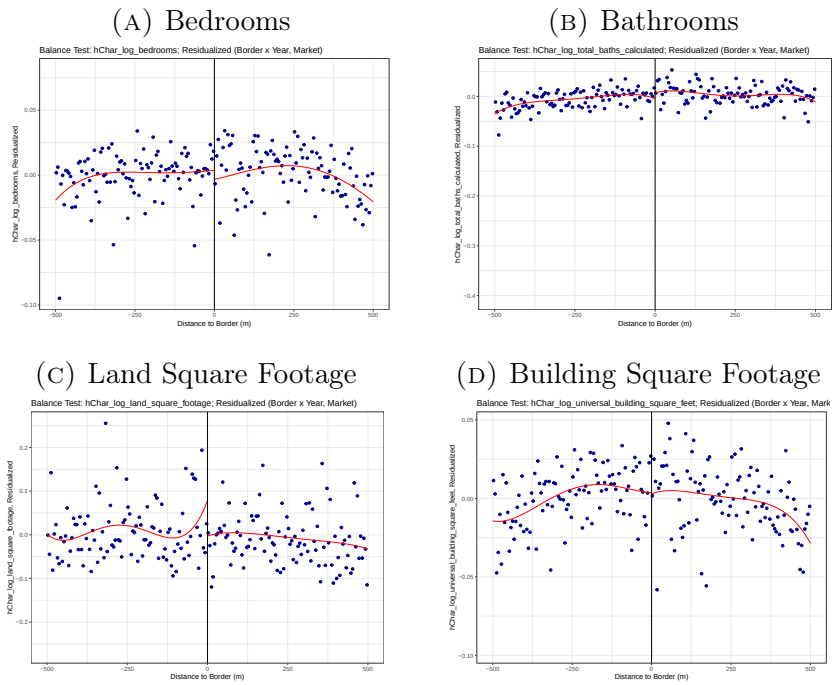
TABLE D5. Do Residents Care about Water Quality?

	House price + water expenses (log)		
	(1)	(2)	(3)
Water pollution[a]	-0.0117**	-0.0115**	-0.0135**
	(0.0053)	(0.0046)	(0.0054)
Any Tier I violation notification			-0.0349**
			(0.0103)
House and demographic attributes[b]	Yes	Yes	Yes
Border × Year FE	Yes	Yes	Yes
School district FE	No	Yes	Yes
City/county FE	No	Yes	No
Observations	910,209	910,209	910,226
R^2	0.805	0.810	0.805

Notes. This table presents OLS estimates based on house transactions in California from 2003 to 2019. Standard errors, clustered at the boundary-year level, are shown in parentheses. Statistical significance is indicated as follows: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The dependent variable is the sum of the transaction price of the house and the present value of the water expenses at the year of sale, calculated over the next 14 years. a. "Water pollution" is measured as the average percentage of contamination exceeding the maximum contamination level (MCL), excluding disinfection byproducts and residualizing to correct for seasonality in contaminant readings. b. Controls include house attributes such as number of bedrooms, bathrooms, building and land square footage, and flexible controls for the year in which the house was built, along with Census block-group level demographics, including race, education, and median household income.

Notably, Column (3) shows that, even when controlling for the continuous measure of water quality, a Tier I violation notification within the five years preceding the sale negatively impacts house prices, leading to an average 3.5% decrease. While this estimate is smaller than the 9.9-16.5% reduction attributed to nearby shale gas development (which heightens groundwater contamination risks) in Pennsylvania, as documented by Muehlenbachs et al. (2015), it remains both statistically and economically significant. This finding suggests that notifications may influence residents' incomplete perceptions of water quality or that residents prioritize short-term, acute water quality concerns linked to Tier I violations over longer-term issues that do not require immediate action. Following Bayer et al. (2007), we show on figure D5 that house characteristics do not jump discontinuously at the boundaries of public drinking water systems, lending further credibility to the boundary discontinuity design used in our main analysis.

FIGURE D5. House Attributes are Continuous across System Boundaries



Notes: We report regression discontinuity plots at the boundaries of water systems using the rdplot command from the R package rdrobust by Calonico et al. (2014). A negative distance to the boundary denotes a house on the "polluted" side of a boundary, and vice versa.

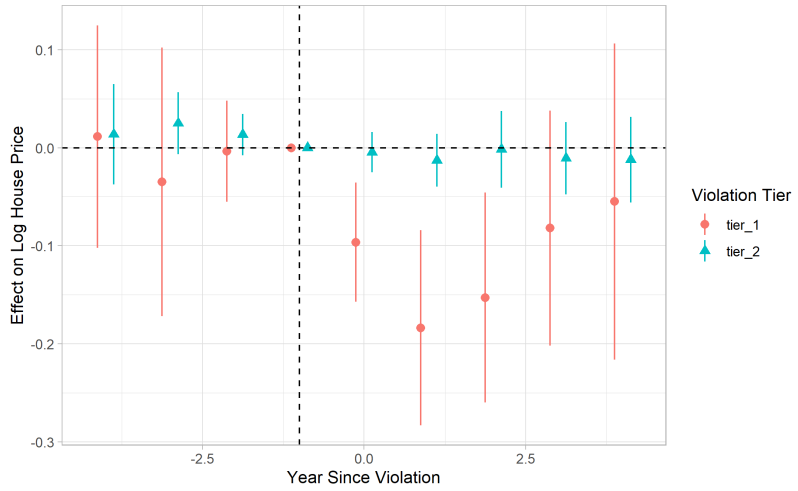
D.3. **Evidence from a within-jurisdiction design.** To alleviate concerns that the effects of water pollution on house prices reported from our reduced-form and structural water-boundary design exercises might stem form unobserved differences in amenities across public water systems boundaries, we also report estimates from an event study evaluating the changes in house prices within an entity following a health-based drinking water violation. Denoting a water system by j with violation event e in year t, and a house by h, we estimate

$$\log p_{hjet} = \beta x_{ht} + \phi_{je} + \mu_t \tag{18}$$

$$+ \sum_{\tau} \delta_{\tau}^{I} \; I_{j,t,e}^{\tau} \mathbb{1}\{e \text{ is Tier I}\} \tag{19}$$

$$+ \sum_{\tau} \delta_{\tau}^{II} \; I_{j,t,e}^{\tau} \mathbb{1}\{e \text{ is Tier II}\} + \epsilon_{hjet} \tag{20}$$

FIGURE D6. Event Study: Effects of Violations on House Prices



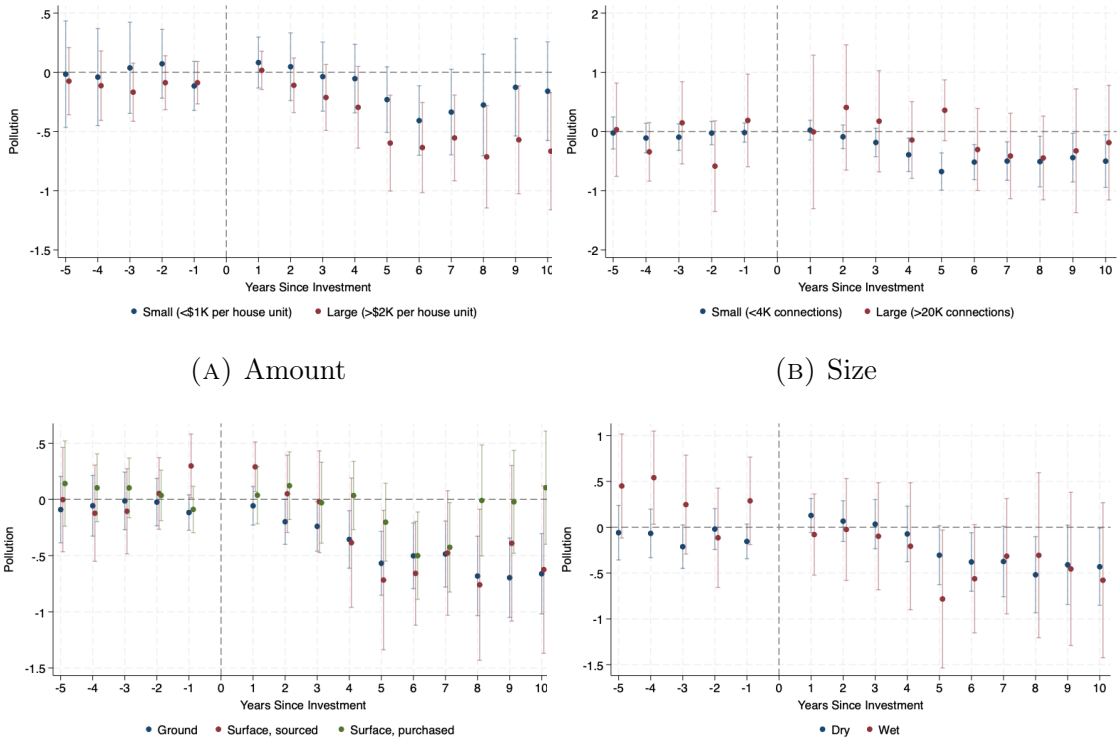
Notes: This figure presents estimates from the event-study specification 20estimated with a two-way fixed effects estimator. We report point estimates and 95% confidence intervals for Tier I and Tier II violations. Standard errors are clustered at the system-violation event level.

The treatment dummy $I^{\tau}_{j,t,e}$ equals 1 if the violation e occurred τ years from year t by jurisdiction j, and the specification includes event-specific water system fixed effects and year fixed effects, to account for systems with multiple violations over our sample. We control for a rich set of house characteristics x_{hjet}, as in our boundary discontinuity designs. We estimate the dynamic treatment effects δ_{τ} separately for Tier I and Tier II violations, to allow for different levels pollution to impact house prices differently. Moreover, the information available to residents and potential house buyers might be different as Tier I violations have stringent and immediate reporting requirements -residents are notified within 24 hours. We report dynamic treatment effects estimates in Figure D6. Consistent with Table D5 and with our main analysis, we find that Tier I violations adversely impact house prices in the medium run. As these effects are within water systems, they cannot be explained by cross jurisdiction differences in amenities.

APPENDIX E. INFRASTRUCTURE INVESTMENTS: HETEROGENEITY IN EFFECTS

E.1. **Homogeneous effects of investment on water quality.** Figure E7 presents the dynamic effects of investment on water pollution, using specification (12), for different sub-samples of the data: below-25th percentile and above-75th percentile groups for a given criterion (investment size, system size, and climate) or thee groups

FIGURE E7. Investment Effectiveness Across Water System Types



(A) Amount

(B) Size

(C) Water Source

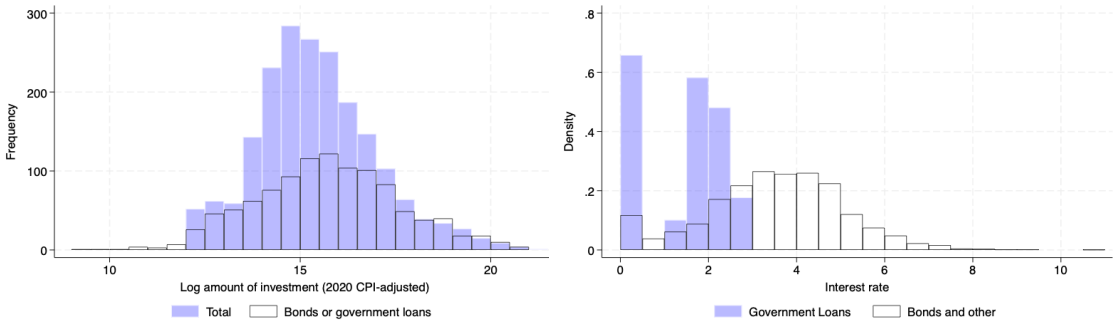
(D) Precipitation

Notes: Each plot presents the coefficient estimates of the dynamic effects of investment on water pollution, using specification (12), for two sub-samples of the data: below-25th percentile and above-75th percentile groups, based on the amount of the investment (Panel A), the size of the system as measured by the number of connections (Panel B), and the average annual amount of rain during the period of study (Panel D), as well as the three groups by the source of water (groundwater, surface water drawn within the jurisdiction, or purchased surface water; Panel C).

depending on the source of water. We do not find evidence for a large heterogeneity in the effects by the amount of the investment (Panel A), the size of the system as measured by the number of connections (Panel B), the source of water (groundwater, surface water drawn within the jurisdiction, or purchased surface water; Panel C), or the climate as represented by the average annual amount of rain during the period of study (Panel D).

E.2. **Heterogeneous costs of investment.** Figure E8 describes the heterogeneity in the investment amount and the coupon rates. Panel (A) presents the distribution

FIGURE E8. Heterogeneous Investment Costs



(A) Amount (B) Interest Rate

Notes: Panel (A) presents the distribution of the log amount of investment in 2020 CPI-adjusted dollars, based on the observed 1,979 investment cases (in blue) and overlays the distribution of the log amount of financing through government loans or other long-term debts, based on the 1,074 investment cases where such financing was used (in white). Panel (B) shows the distribution of the coupon rates by the debt type (federal/state government loans in blue vs. other long-term debts like municipal bonds in white).

of the log amount of investment in 2020 CPI-adjusted dollars, based on the observed 1,979 investment cases. The median investment size is $4.38 million while the average is $23.64 million. The panel also presents the distribution of the log amount of financing through government loans or other long-term debts, based on the 1,074 investment cases where such financing was used. It is notable that only 54% (=1,074/1,979) of realized investment cases involved financing, while the rest is through federal/state grants. These external funding is dominant for smaller investments; the median financing size is $6.45 million with the mean being $38.23 million, both larger than the corresponding statistics for the total investment size.

Panel (B) of Appendix Figure E8 shows that the coupon rate also differs across local governments, depending on the debt type (federal/state government loans vs. other long-term debts like municipal bonds). For federal/state government loans, zero interest rate is not uncommon, with the average rate being 1.32% and the maximum 2.57%. These loans are largely subsidized, as the interest rates in other long-term debts are much higher, with the mean of 3.49% and the maximum of 10.60%.

Appendix F. Estimation of Local Political Frictions Parameters

F.1. **Estimation details.** For a given parameter vector $\boldsymbol{\psi}$, we solve the policymaker's dynamic program by value function iteration on a discretized (l^r, l^q) state space representing rate and expected pollution investment stock variables. These stocks are repleted when investment occurs and depreciate over time to match the shape of our event studies estimated in Figure 2. To reduce the computational complexity, we assume that the governing body does not anticipate future changes in x_{jt}.[3] In each state (l^r, l^q), we first construct residents utility using the estimated willingness-to-pay $u\big(q_{jt}, r_{jt}; \omega(y_i)\big)$ and aggregate resident utilities into the policymaker's flow payoff using the income-specific turnout rates:

$$\Pi_{jt}(l^r, l^q; \boldsymbol{\psi}) = \sum_y \lambda(x_{jt}; \boldsymbol{\psi})\, \tilde{\pi}_{jt}(y)\, u\big(q_{jt}(l^q), r_{jt}(l^r); \omega(y)\big),$$

where $q_{jt}(l^q)$ and $r_{jt}(l^r)$ denote the mappings from the grid states (l^q, l^r) into current pollution and rates. Note that critically, our measure of accountability A_j is allowed to influence the weight $\lambda(\cdot)$. The law of motion for the discretized state variables implied by our event study estimates are described in Equations 5 and 6. Given these primitives and the private cost of investing $\kappa(x_{jt}; \boldsymbol{\psi})$, we solve the optimal policy of each governing body, in each time period using value function iteration. We thus recover the choice-specific value difference $\Delta V_{jt}(l^r, l^q; \boldsymbol{\psi})$ and implied conditional choice probabilities

$$P(a_{jt} = 1 \mid l^r, l^q, x_{jt}; \boldsymbol{\psi}) = \frac{\exp(\Delta V_{jt}(l^r, l^q; \boldsymbol{\psi}))}{1 + \exp(\Delta V_{jt}(l^r, l^q; \boldsymbol{\psi}))},$$

which we evaluate at observed states and use to construct the log-likelihood

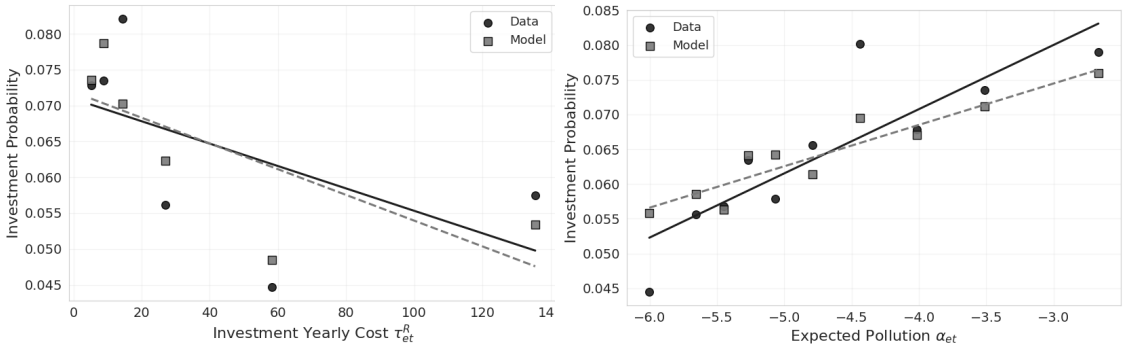
$$\ell(\boldsymbol{\psi}) = \sum_{j,t} a_{jt} \log P(a_{jt} = 1 \mid l^r_{jt}, l^q_{jt}, x_{jt}; \boldsymbol{\psi}) \tag{21}$$

$$+ (1 - a_{jt}) \log\big(1 - P(a_{jt} = 1 \mid l^r_{jt}, l^q_{jt}, x_{jt}; \boldsymbol{\psi})\big) \tag{22}$$

We maximize the average log-likelihood using gradient-based optimization, with automatic differentiation and GPU acceleration using PyTorch.

[3] We've also experimented with a perfect foresight assumption that combined an infinite horizon final period with backward induction, and found similar estimates. Both of these approaches provide a parsimonious way to focus on the dynamics of rate and pollution induced by investment while still capturing local differences in demographics and natural amenities. Given the many variables included in x_{jt}, incorporating beliefs over all these states would substantially increase the size of the state space.

FIGURE F9. Model Fit on Investment Patterns



(A) Costs (B) Pollution

Notes: This figure shows the model fit along two specific dimensions. Panel (A) shows that the model reproduces the decreasing relationship observed in the data between investment probability and the magnitude of water rate increases from investment. Panel (B) shows that the estimated model successfully reflects that investment is more likely to occur in system-years where expected pollution is likely to be higher, for exogenous reasons such as weather and the water source used.

F.2. **Model fit.** Figure F9 evaluates the model's ability to reproduce key empirical investment patterns. Panel (A) examines the relationship between investment probability and the magnitude of water rate increases associated with investment. In the data, investment becomes less likely as the implied cost of investment rises, reflecting the higher financial burden on residents. The model closely matches this declining relationship, indicating that the estimated cost component of the policymaker's payoff captures the observed sensitivity of investment decisions to financing costs. Panel (B) examines how investment probability varies with expected pollution levels. Both the data and the model show that investment is more likely when expected pollution is higher, reflecting greater expected benefits from improving water quality. Overall, the figure shows that the estimated model successfully reproduces two central empirical patterns: investment is less likely when costs are high and more likely when environmental need is greater.