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# The effects of ownership and benchmark competition: An empirical analysis of U.S. water systems<sup>☆</sup>

Scott Wallsten<sup>\*</sup>, Katrina Kosec

*American Enterprise Institute and AEI–Brookings Joint Center, 1150 17th Street, NW Washington, DC 20036, USA*

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## Abstract

Should governments or private firms own water systems? Can yardstick, or benchmark, competition effectively discipline utilities? Little empirical research sheds light on these issues. We use a panel dataset that includes every community water system in the United States from 1997 to 2003 to test the effects of ownership and benchmark competition on regulatory compliance. We find that ownership does not generally affect compliance with the Safe Drinking Water Act (SDWA). Greater benchmark competition, however, is associated with fewer SDWA violations. The results suggest that ownership, *per se*, may not matter much, but that competition – even in its weaker form of benchmarking by consumers or regulators – can improve performance.

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## 1. Introduction

Privatizing utilities remains controversial, though most studies suggest that it yields positive outcomes. Those positive outcomes, however, are much more robust in industries that support rigorous competition, like telecommunications. What about industries in which competition is more difficult to introduce or sustain? Is a private monopoly likely to outperform a state-owned

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<sup>\*</sup> Corresponding author. Tel.: +1 202 969 2950.

*E-mail addresses:* [scott@wallsten.net](mailto:scott@wallsten.net) (S. Wallsten), [kkosec@stanford.edu](mailto:kkosec@stanford.edu) (K. Kosec).

monopoly? Can yardstick, or benchmark, competition discipline private or public providers in the absence of head-to-head competition? This paper attempts to answer these questions in the context of drinking water systems in the United States.

The ideal form of ownership in network industries remains heavily debated. Water privatization in the United Kingdom, for example, is still a hot issue nearly twenty years after Margaret Thatcher sold ten regional water authorities and established a new regulator. In the United States, where nearly all utilities are owned or operated by private firms, around 80% of the population receives water from publicly-owned systems.

Proponents of private ownership argue that firms can deliver services more efficiently than can governments. Governments have diverse and often contradictory objectives that can lead to a misallocation of resources, and may face incompatible incentives when they act as both owner and regulator of a utility. In addition, politicians may feel pressure to provide jobs in the utility to constituents, for example, rather than investing in the water network.

Opponents of private ownership counter that privatization is difficult and impractical given water and sewerage externalities and the limited scope for competition. Some object to the very idea of considering water an economic good or allowing a private company to run a water system. [Public Citizen \(2004\)](#), an outspoken critic of privatization, highlights the intense feelings regarding water privatization, claiming that “perhaps the greatest theft of common resources facing humanity and the planet is the corporate takeover of the world’s water.”

While direct competition among piped water systems is essentially nonexistent, benchmark, or yardstick, competition may be possible. [Shleifer \(1985\)](#) formalized a model of regulation via yardstick competition in which a regulated firm’s prices depend on other firms’ costs. Benchmarking may also apply to observable information other than prices. Even if consumers cannot choose who supplies their drinking water, utilities may face performance pressure if consumers or regulators can compare systems. Consumers dissatisfied with their utilities could express their displeasure through their elected representatives, while regulators could use the information from benchmark comparisons to demand price or quality changes with potentially dramatic effects on firms in the future.

Despite the passions the issue raises, there is scant empirical evidence on whether public or private water systems tend to perform better and whether benchmark competition actually improves outcomes. To our knowledge, no systematic, empirical analysis compares public and private water systems in the United States and we are not aware of any empirical literature exploring the potential impact of benchmark competition in the water sector. We address these gaps by exploring U.S. water quality and household expenditures on water by system ownership type and the degree of benchmark competition faced. In particular, we use a panel dataset that includes every community water system in the country from 1997 to 2003 to test the effects of ownership and benchmark competition on violations of the Safe Drinking Water Act (SDWA).

Controlling for location fixed effects, income, the share of the population that is urban, ownership concentration in the local water market, system size, water source, and year fixed effects, we find little difference between public and private ownership with regard to SDWA violations. Among smaller water systems, private ownership is associated with fewer violations of maximum contaminant levels but more monitoring and reporting violations than public systems. Among larger systems – especially those serving more than 100,000 people – private ownership is associated with more contaminant but fewer monitoring and reporting violations.

The results neither support critics of private ownership nor suggest that private ownership is superior. Overall, compliance with SDWA regulations does not appear to depend much on system ownership. Benchmark competition, however, appears to have a more robust impact. Greater

benchmark competition, as measured by the concentration of the share of connections held by water systems in each county, is associated with both fewer contaminant and fewer monitoring and reporting violations. This suggests that even a weak form of competition can have positive effects on regulatory compliance. Overall, our results are consistent with the hypothesis that public or private ownership may not make much of a difference when the operator is largely monopolistic, but that even then, benchmark competition can yield tangible benefits.

## 2. The economics of water systems

Water and sewerage service provision entails unique challenges. Fixed costs are high, barriers to entry are large, the potential for competition is limited, and the sector has many and large externalities. The long-lived fixed assets create incentives for both firms and governments to delay investment and use revenues for other purposes. Governments often encounter political and legal obstacles to privatization, and private investors worry that governments will expropriate their assets.

While direct competition in water provision is difficult, indirect competition is more feasible. Such competition could take the form of private firms competing for operation and management contracts (competition for the market) or benchmark competition, where the existence of a large number of water systems could allow consumers and regulators to compare their system to others and accordingly pressure their own utility to improve performance.

Water services may be subject to a variety of market failures that require government involvement or regulation. Externalities, especially health-related, are especially pronounced in water and sewerage, complicating private sector involvement.<sup>1</sup> Externalities necessitate mechanisms of ensuring that prices, investment, and other operational decisions are not divorced from externalities that affect actors other than firms.

Some features of water and sewerage infrastructure create incentives for both governments and firms to delay investment. Much of the sector's assets, such as the pipes, are sunk, have no alternative uses, and are very long-lived. Because the fixed costs comprise a large share of total costs and because the system can operate for a long time without much intervention, a self-financing utility will earn quasi-rents (Noll, 2002). Both politicians and investors may feel pressure to use the quasi-rents for short-term priorities rather than investment. Consumers may demand lower tariffs, and governments that own and operate their water systems may face pressure to use revenues for other immediate needs. Private operators, meanwhile, may worry about expropriation and face investor pressure to avoid reinvesting the quasi-rents.<sup>2</sup>

### 2.1. *The evidence on private versus public ownership*

A number of studies have evaluated privatization in many industries around the world. Megginson and Netter (2001) and Shirley and Walsh (2000) find in comprehensive literature reviews that privatization has generally improved efficiency. Little of that research, however, has focused on

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<sup>1</sup> The extent to which health is actually an externality depends on whether consumers and the utility bear the full costs of any health impacts. Nonetheless, absent some type of oversight consumers have little means of monitoring the health quality of their water.

<sup>2</sup> U.S. water systems in the 19th century were largely privately run, though cities began to municipalize them in the early 20th century. Troesken and Geddes (2001) argue that municipalization occurred because private firms were underinvesting in their networks, and that this underinvestment occurred because the municipalities could not credibly commit to not expropriating their resources. They conclude that underinvestment was a rational response to the fear of expropriation.

water. Because privatization has been combined with competition in sectors like telecommunications, it is less clear whether government or private ownership is inherently superior when the potential for competition is limited. Without appropriate incentives – in the form of regulation, some type of oversight, or a viable threat of entry in some sphere of operations – it is not obvious that a private monopoly would be better than a public monopoly.

Existing research comparing public versus private ownership of water provision consists primarily of case studies, from which it is difficult to generalize. Case studies are usually not chosen randomly, but rather tend to focus on exceptional cases.<sup>3</sup> For water services, those cases often focus on spectacular failures, such as the disastrous privatization attempt in Cochabamba, Bolivia.<sup>4</sup> However, at least 25,000 U.S. water systems are privately owned, and other countries like France rely heavily on the private sector without disastrous consequences, suggesting that the relatively small number of spectacular failures may not be representative.<sup>5</sup>

Case studies of water ownership in industrialized countries are inconclusive. *The Economist* (2003) argues that water privatization in the UK has been successful when compared to water systems in Scotland, which went from private to public hands. Saal and Parker (2001), contrarily, find higher prices but little productivity improvement following the UK privatization. Likewise, Cowan et al. (2000) estimate that privatization in the UK led to a net welfare loss.

Most of the few empirical studies on water privatization lack good, consistent data and yield generally inconclusive results. One exception is a study by Galiani et al. (2003), who rigorously explore the effect of water privatization on child mortality in Argentina. They find that child mortality fell eight percent in regions that privatized their water systems, and that the effects were largest in the poorest areas.<sup>6</sup> Clarke et al. (2004) find in a household-level study of developing countries that connection rates to piped water increased following privatization, even among the poor, but that connection rates increased similarly in areas that did not privatize.

Empirical research on the effects of private sector participation in industrialized countries focuses largely on operating efficiency, and is inconclusive. Several studies in the 1980s using fairly small datasets (120 observations and fewer) found no significant differences between public and private water system efficiency in the U.S. (Byrnes et al., 1986; Feigenbaum and Teeple, 1983; Teeple and Glycer, 1987). Bhattacharyya et al. (1995), however, found in a sample of 190 public and 31 private water systems that private (public) operators tended to be more efficient among small (large) systems. Renzetti and Dupont (2003) concluded that the literature found little evidence of “unambiguous improvements” from privatization, but that public–private partnerships might be promising.

While existing empirical studies on the effects of ownership focus primarily on operating efficiency, critics also worry that private operators may give less weight to public interest than

<sup>3</sup> Shirley (2002) is an exception. This collection of six water privatization case studies was undertaken with a coherent framework meant to ensure that the cases, in countries with varying institutional and physical characteristics, were evaluated in a consistent manner.

<sup>4</sup> A focus on failures is not surprising — they may involve large amounts of money and affect large populations. Atlanta, for example, signed a 20-year, \$428 million management contract with a private operator in 1998, only to cancel it a few years later as both the city and the firm accused the other of violating the contract (Brubaker, 2003).

<sup>5</sup> In 2003 private operators owned 25,977 community water systems (Environmental Protection Agency, 2003). A former water analyst for Public Citizen noted that “Contrary to the critics’ contentions, private operators have a respectable record of providing quality water and complying with environmental standards” (Tsybine, 2002).

<sup>6</sup> Their analysis is rigorous: the authors hone their findings by separating mortality that can be caused by water conditions from mortality unrelated to water. Privatization was uncorrelated with mortality from non-water causes, but strongly correlated with mortality caused by water conditions. Moreover, the measured effect may be underestimated since their water access data under-sampled the poorest areas, which appeared to receive the largest benefits.

would a government operator, resulting in lower quality water. To our knowledge no large-scale empirical studies have explored the effects of ownership on water quality in industrialized countries. In a publicly available presentation, [Gasteyer and Vaswani \(2004\)](#) use some of the Environmental Protection Agency (EPA) data that we use, but only with cross-sectional data and county averages.<sup>7</sup> They conclude that private operators have slightly more contaminant violations of the SDWA. No research appears to have explored competition in water, to the extent that it might exist.

### 3. Regulation and competition

The Safe Drinking Water Act (SDWA) of 1974 covers all of the approximately 160,000 public water systems in the United States and allows the EPA to set maximum acceptable contaminant levels, outline water treatment procedures, and require water systems to follow a prescribed water quality monitoring schedule.<sup>8</sup> The EPA also regulates the states, localities, and water suppliers that implement those standards.<sup>9</sup>

Water rates appear to be regulated inconsistently across the country ([Mann, 1993](#)). Unfortunately, to our knowledge, there are no recent surveys of state and local water regulators or regulations. A 1989 survey, however, found that in general states regulate private but not state-owned utilities ([Beecher and Laubach, 1989](#)). [Mann \(1993\)](#) notes that mayors, city councils, or other elected or appointed representatives generally approve rates of water systems owned by the government. In other words, the evidence suggests that with some exceptions, both public and private water systems are subject to some pricing oversight — directly by regulators in the case of private firms, or by politicians who must approve prices in the case of government-owned utilities. Perhaps in part because of scant data, there is little research on water rate regulation. [Wolak \(1994\)](#) models the interactions between regulators and water utilities under asymmetric information in order to uncover the utility's cost function. [Timmins \(2002\)](#) estimates the objective function of regulators and estimates the deadweight loss caused by the consistent underpricing of water relative to its marginal cost.

In addition to regulatory or political constraints on utilities' behavior, they may also face pressure from benchmark competition (along the lines of [Shleifer, 1985](#)). While there does not appear to be any empirical analysis of benchmark competition, based largely on interviews

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<sup>7</sup> Our analysis improves on theirs in a number of ways that allows us to explore the data more rigorously. First, we use a panel dataset covering 1997–2003, while they use only a cross-section from year 2000. Second, our contaminant analysis is at the level of the water system, while they use county averages. That is, for the contaminant analysis we use the ownership status of each water system rather than the share of water systems in a county that are public or private. Third, we use an econometric approach suited to this type of data that allows us to control for many factors other than ownership that might affect quality. Contrarily, [Gasteyer and Vaswani](#) show only a regression line highlighting the correlation between ownership share and average number of violations in the county.

<sup>8</sup> Testing must be carried out by state- or EPA-certified laboratories. Any members of a water utility or lab found guilty of deliberately falsifying data can be prosecuted and jailed. Certified labs must also pass periodic on-site audits. Given these safeguards, the EPA believes that its data are collected in a uniform manner and are reliable.

<sup>9</sup> See the EPA's SDWA website for details: <http://www.epa.gov/safewater/sdwa/index.html> (last accessed 3/3/05). The 1986 amendments expanded the SDWA's scope to protect aquifers from pollutants and develop drinking water standards for previously unregulated contaminants. The 1986 revision added 83 additional contaminants to the list ([Sapat and Teske, 2004](#)). In 1996, several new amendments emphasized protecting source water, mandated operator training and certification, and required water systems to provide information on water quality to consumers. (See <http://www.epa.gov/safewater/sdwa/30th/factsheets/understand.html> (last accessed 3/3/05) and <http://www.epa.gov/safewater/sdwa/theme.html> (last accessed 3/4/05)).

Sawkins (1995) concludes that yardstick competition improved water regulation in England and Wales.

Benchmark competition could work through a number of mechanisms. In the United States, the EPA posts detailed system-level water quality data on its website and requires water systems to submit annual consumer confidence reports to consumers and regulators. These reports include a listing of all violations of EPA health regulations, the potential sources of contamination, and the likely health effects. The purpose of these reports, according to the EPA, is to “enable Americans to make practical, knowledgeable decisions about their health and their environment.”<sup>10</sup> Consumers and regulators can compare their water quality to industry benchmarks and pressure systems that fall short.

Our comprehensive water system-level panel dataset, derived from data collected by the EPA under the SDWA and data collected by the U.S. Census, allows us to shed light on the effects of ownership and benchmark competition on water quality (as measured by compliance with water quality regulations). We discuss our data, empirical approach, and results below.

#### 4. Data and analysis

The 1996 SDWA amendment requires the EPA to collect data and make much of it public.<sup>11</sup> We obtained data on each community water system in the United States from the EPA’s Safe Drinking Water Information System, Federal Version (SDWIS/FED).<sup>12,13</sup> The SDWIS/FED contains data on every public water system in the United States, including tribal areas and U.S. territories. As discussed above, water systems must periodically test their water and report results to the state.<sup>14</sup> The state, in turn, determines whether water systems are complying with the regulations and reporting violations to the EPA periodically as prescribed.<sup>15</sup> The EPA records this information in the SDWIS/FED, which therefore contains data on violations of maximum allowed contaminant levels as well as treatment and reporting violations.<sup>16</sup> The EPA reports violations as discrete events annually, so the dataset reveals, for example, how frequently water supplied by each water system exceeded the maximum allowed levels of certain contaminants in a

<sup>10</sup> <http://www.epa.gov/safewater/ccr/frequentquestions.html> (last accessed 6/11/06).

<sup>11</sup> Recent data are available online and older records are available via freedom of information act request.

<sup>12</sup> We are grateful to Lee Kyle of the EPA Office of Water for extracting these data for us and patiently answering our many questions and requests for additional data. The authors, however, are solely responsible for any mistakes made in using or interpreting the data.

<sup>13</sup> A community water system is a public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

<sup>14</sup> The EPA establishes how often systems must monitor water supplies for chemicals based on system characteristics. For instance, if a system has had no violations of a certain contaminant and is located in an area where the contamination risk is low, the system can apply for an exemption from testing for that contaminant as frequently as would otherwise be required. See: [http://www.epa.gov/safewater/pws/pdfs/qrg\\_smonitoringframework.pdf](http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf) (last accessed: 12/14/04).

<sup>15</sup> According to 40 CFR part 142, Section 15: “Each State...shall submit quarterly reports to the Administrator on a schedule and in a format prescribed by the [EPA] Administrator, consisting of the following information: (1) New violations by public water systems in the State during the previous quarter of State regulations adopted to incorporate the requirements of national primary drinking water regulations, including violations of the public notification requirements....” See <http://www.epa.gov/safewater/regs.html# CFR> (last accessed 12/15/04).

<sup>16</sup> A treatment violation is a failure to properly treat a drinking water source in order to reduce the level of a specified contaminant. A reporting violation is a failure to collect the required number of samples (including confirmation samples) in the specified time frame, a failure to ensure the samples are analyzed properly, or a failure to submit required monitoring information.

Table 1  
Number of active systems in 2003

Ownership	System size				
	Very small	Small	Medium	Large	Very large
Private	21,774	3751	630	458	50
Local govt.	6469	9359	3716	2879	309
State govt.	205	241	75	30	1
Federal govt.	137	108	87	67	0
Native American	452	165	26	3	0
Public/private	711	619	135	66	6
Unknown	547	132	24	13	0
Total	30,295	14,375	4693	3516	366

Note: Size categories established by US EPA based on average daily population served: Very small: 25–500, Small: 501–3300, Medium: 3301–10,000, Large: 10,001–100,000, Very large: 100,001+.

given year, but not by how much.<sup>17</sup> The data also include self-reported information on system ownership, number of service connections, population served, primary water source, and the geographic location of each water system.

U.S. water systems vary across many dimensions, making them ideal for testing the *ceteris paribus* effects of such characteristics as ownership or water system size. Systems range from small public utilities serving as few as 25 people and relying on ground water to large private utilities providing treated surface water to millions of customers.

Ownership categories include private, federal, state, local (municipal), tribal, public/private, and unknown. Private sector involvement can range from complete ownership and operation to small contract operations work. We had hoped that the public/private category would capture these contract operations. Unfortunately, according to the EPA, “Public/Private” has no explicit definition and the category is not used consistently.<sup>18</sup> Fewer than four percent of water systems classified themselves as Public/Private. Primary water source categories include ground water, surface water, purchased ground water, purchased surface water, and ground water influenced by surface water. Different types of water may be more prone to contamination or to higher final water prices, and it is thus important to control for the primary water type.

The resulting panel dataset covers 1997–2003 and includes 377,629 active water system-years.<sup>19</sup> While the precise number of water systems changes each year, for 2003 the dataset contains 90,421 community water systems, of which 53,245 are active.<sup>20</sup> Table 1 shows the number of water systems by ownership status and size category, and Table 2 shows the total number of service connections by ownership and size.

The tables reveal that most water systems are private, but that those systems tend to be very small. A casual inspection of the names of very small systems suggests that they are largely mobile home parks, apartment and condominium complexes, and resorts and hotels. Nonetheless, a substantial number of medium to large systems are private, although the very largest (those that

<sup>17</sup> See <http://www.epa.gov/safewater/mcl.html> for a list of contaminants; <http://www.epa.gov/OGWDW/mdbp/ieswtr.html> for the Federal Register notice on water treatment techniques, and [http://www.epa.gov/safewater/mdbp/qrg\\_st1.pdf](http://www.epa.gov/safewater/mdbp/qrg_st1.pdf) for a brochure on water treatment.

<sup>18</sup> Conversations with Lee Kyle, EPA Office of Water, 6/17/04 and 12/3/04.

<sup>19</sup> The violations data extend back to 1976, but a record of ownership begins only in 1997.

<sup>20</sup> Inactive water systems are those reported to the EPA as being inactive as well as those that reported in one year and not at all in the following year.

Table 2  
Total population served in 2003

Ownership	System size				
	Very small	Small	Medium	Large	Very large
Private	3,082,896	4,564,502	3,608,747	13,691,534	19,550,550
Local govt.	1,547,284	13,854,549	21,707,493	81,009,849	102,691,886
State govt.	44,854	373,175	420,248	805,723	103,414
Federal govt.	26,502	188,273	519,075	1,507,352	0
Native American	82,764	223,255	141,477	48,860	0
Public/private	146,950	880,510	684,030	1,517,788	1,275,450
Unknown	79,223	184,846	148,678	307,092	0
Total	5,010,473	20,269,110	27,229,748	98,888,198	123,621,300

Note: Size categories established by US EPA based on average daily population served: Very small: 25–500, Small: 501–3300, Medium: 3301–10,000, Large: 10,001–100,000, Very large: 100,001+.

serve over 1,000,000 — not identified separately in the table) are owned only by local governments.

Private and local systems account for more than 90% of all community water systems. Water systems owned by states appear to serve primarily prisons and universities. Federally-owned systems serve military bases, national parks, and some prisons. Finally, Native American tribes often own and operate their own water systems.

As described above, the SDWIS/FED contains data on violations of the maximum allowed level of a number of health-related contaminants, treatment techniques, and monitoring and reporting.<sup>21</sup> Table 3 shows the average number of these violations by system ownership and size from 1997 to 2003. The average number of health-based contaminant violations is small — generally less than 0.1 per system, per year. The average, however, masks variation across system types. Water systems owned by Native American tribes tend to experience the most frequent contaminant violations, followed by private systems and then local systems. Federally-owned systems report the fewest violations of health-based maximum contaminant levels.

Violations by size give a somewhat different view. Smaller systems tend to have the largest number of violations of all types, although “large” water systems appear, on average, to have almost as many contaminant violations as very small systems. Differences across size mean that simple comparisons across ownership types may be deceptive, as certain types of systems are more likely to be of a certain size. Typically, larger systems have more sampling points, and a violation at any sampling point counts towards the total number of violations. One might therefore expect more violations in larger systems for reasons that have little to do with inherent water quality. This observation also means that a larger average number of violations in small systems may be even worse than the figure implies since all else equal, systems with fewer sampling points should have fewer measured violations.

<sup>21</sup> The EPA compiles data on the number of violations per water systems per year. It is not obvious how best to use this variable. One might normalize or weight it by population served on the grounds that a violation in a large system potentially affects more people than a violation in a small system. However, we used the unweighted number of violations per system because larger water systems typically sample their water at more locations than smaller systems. Large systems can thus receive more violations than smaller systems since a violation at any sampling point counts as a separate violation. (conversation with Abe Siegel, EPA Office of Water, 2/2/05). As such, we considered the variable — violations per system per year — to be already normalized, albeit imperfectly. These facts, however, make it especially important to control for the size of the water system since size will be correlated with the number of violations.

Table 3  
SDWA violations by system ownership, size, and primary water source

	Maximum contaminant level violations	Treatment technique violations	Monitoring and reporting violations
<i>Ownership</i>			
Federal govt.	0.049	0.041	1.312
Local govt.	0.095	0.065	0.691
Native American	0.122	0.091	4.983
Private	0.103	0.031	1.449
State govt.	0.075	0.025	1.016
<i>Size</i>			
Very small	0.106	0.037	1.48
Small	0.088	0.054	0.653
Medium	0.083	0.055	0.619
Large	0.101	0.087	0.738
Very large	0.045	0.141	1.061
<i>Primary water source</i>			
Ground water under the influence of surface water (GU)	0.075	0.353	3.029
Purchased ground water under the influence of surface water (GUP)	0.029	0.174	1.377
Ground water (GW)	0.105	0.018	1.166
Purchased ground water (GWP)	0.059	0.013	0.299
Surface water (SW)	0.161	0.292	1.65
Purchased surface water (SWP)	0.037	0.026	0.29

Note: very small systems serve 25–500 people, small serve 501–3300, medium serve 3301–10,000, large serve 10,001–100,000, and very large serve more than 100,000.

Monitoring and reporting violations are the most common violation type, with all but local systems in violation at least once per year, on average. As for contaminant violations, tribal systems experience the most frequent monitoring and reporting violations. Locally-owned systems have, on average, the fewest such violations. Very small systems tend to have higher numbers of monitoring and reporting violations than larger systems. The average number decreases through medium systems and then increases for large and very large systems.

Treatment technique violations are generally the least common violation type. Again, Native American systems are the most frequent violators, followed by local systems and then federal. Private and state-owned systems report the fewest treatment technique violations.

The table also reveals that violation frequency varies across water source. Systems that rely primarily on surface water have the most contaminant violations, and on average have about 50% more violations than systems that primarily use ground water, which has the second-highest number of violations. Ground water under the influence of surface water, meanwhile, generates the most monitoring and reporting and treatment violations. These tabulations emphasize the importance of controlling for water type in any analysis.

#### 4.1. Econometric analysis

As discussed above, the data include the number of violations each year, and we do not have data on the severity of each individual violation. As a result, the dependent variable (violations) is

count data, and should be modeled by an appropriate discrete distribution that accounts for the large number of zeroes and small values. In the case of violations of SDWA rules, it seems appropriate to expect that, for small time intervals, the probability of a violation is proportional to the length of the time interval. This suggests that the dependent variable is drawn from a Poisson distribution with parameter  $\lambda_{it}$ .<sup>22</sup>

$$\Pr(Y_{it} = y_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{y_{it}}}{y_{it}!}, \quad (1)$$

Here,  $y_{it}$  is the number of violations system  $i$  reports in year  $t$ ,

$$\ln \lambda_{it} = \beta' \mathbf{x}_{it}, \text{ and } \mathbf{x}_{it} \text{ is a vector of independent variables.} \quad (2)$$

It therefore follows that

$$E[y_{it}|x_{it}] = \text{Var}[y_{it}|x_{it}] = \lambda_{it} = e^{\beta' \mathbf{x}_{it}} \quad (3)$$

The Poisson distribution, however, assumes that the mean of the variable equals its variance. In our case, the variance of each dependent variable of interest far exceeds the mean, suggesting overdispersion in the data and that a negative binomial distribution (for which the variance is a quadratic function of the mean) is more appropriate (Greene, 1993; Long and Freese, 2003).<sup>23</sup>

The negative binomial regression is similar to the Poisson regression except that

$$\lambda_{it} = \exp(\beta' \mathbf{x}_{it} + \varepsilon_{it}) \text{ and } E(\varepsilon_{it}) = 0. \quad (4)$$

As noted above,  $y_{it}$  is the number of violations in system  $i$  in year  $t$ . We focus on contaminant level and monitoring and reporting violations, as the number of treatment technique violations is too small to generate consistent results. The vector  $\mathbf{x}_{it}$  includes system size and dummy variables indicating ownership type. Because of the differences by system in size and ownership, we also interact the ownership variables with five size category dummies. Because water quality and the economics of drinking water provision can be affected by the physical and topographical characteristics of the water system's location (Noll, 2002), we also control for location fixed effects-dummy variables indicating in which "core-based statistical area" (CBSA) the water system is located.<sup>25</sup> All the fixed effect dummies equal zero for water systems not located in any CBSA. We also include dummy variables indicating the water source (e.g., groundwater or

<sup>22</sup> See Greene (1993), pp. 676–679.

<sup>23</sup> The means and variances (mean, variance) of the violations are: contaminant (0.10, 0.27), treatment (0.05, 0.23), monitoring (1.14, 54.69).

<sup>24</sup> See Long and Freese (2003) for a description of the negative binomial regression model.

<sup>25</sup> County-level or even system-level fixed effects would be superior to our CBSA fixed effects. Unfortunately, those proved impossible given our resources. First, Allison and Waterman (2002) point out that the STATA procedure for estimating the fixed effects negative binomial regression does not actually control properly for the fixed effects. Second, given that problem in STATA, we did not have enough computer resources to include all 3141 county fixed effects in the equation, let alone 50,000+ water system dummies. However, including fixed effects manually rather than by using STATA's "xt" commands has the advantage of allowing us to use procedures developed by Long and Freese (2003) to simulate expected number of violations for each type of system based on the regression results.

surface water), as this affects inherent water quality, and year fixed effects to account for changes in regulatory oversight or compliance that might change over time, such as utilities gaining experience with the SDWA over time.<sup>26</sup>

We also control for county-level variables, including average county household income and the share of the population that lives in urban areas. These variables come from the 2000 U.S. Census, which means that they unfortunately vary only over county, and not over time. Income and urbanization do not change radically in a short period of time – and differences across counties probably change even less – so these are reasonable proxies for income and urbanization even in years other than 2000.

Finally, while we know of no piped water systems directly competing with one another for given households, the existence of a large number of water systems in a given region may facilitate benchmark competition. We conjecture that utilities face more pressure to perform well in counties with numerous utilities because it is easier for consumers and regulators to compare utilities in geographically similar areas and more difficult for utilities to blame poor quality on factors beyond their control (e.g., geographic factors).

To capture this possibility, we create a Herfindahl–Hirschman Index (HHI) to measure concentration in the water system “industry.” We define a county as a market and the share of the total connections in a county that a water system serves as its market share. A completely monopolistic market would yield an HHI of 10,000, and the U.S. Justice Department deems an industry to be heavily concentrated if the HHI exceeds 1800. Because piped water systems do not compete within the same geographic space and customers do not have a choice of water provider short of moving to a new water district, a more typical HHI calculation would imply a completely monopolistic market. However, we consider our measure of HHI appropriate for exploring benchmark, rather than head-to-head, competition.

Even our measure of benchmark competition, in which a market is a county, suggests a highly concentrated market. The average HHI across all U.S. counties is 4224 — more than twice the Justice Department’s threshold for a “heavily concentrated” industry. Still, nearly one-third of the population lives in counties with at least moderate benchmark competition ( $\text{HHI} \leq 1800$ ).

#### 4.2. Results — no interactions

Table 4 shows both the coefficient estimates and the incident rate ratios (IRRs) resulting from estimating this equation without the interaction variables and with robust standard errors.<sup>27</sup> The table shows that controlling for size, water source, location, year, income, and urbanization, privately-owned firms have fewer contaminant violations, but more monitoring and reporting violations, than do municipally-owned firms. The HHI is positively correlated with violations, suggesting that the number of violations decreases when there is more competition, consistent with the hypothesis that competition – even in its weak benchmark form – improves outcomes.

The table also shows that, in general, the number of violations of either type generally decreases as system size increases. This correlation may reflect the greater resources available to

<sup>26</sup> We drop systems whose ownership status is “unknown” and, unfortunately, systems whose status is “public/private” because those are effectively unknown as well, as discussed above. EPA officials had no priors as to which ownership type these were likely to be.

<sup>27</sup> We adjusted the standard errors for intra-CBSA correlation.

Table 4  
Ownership, competition, and SDWA violations

No interaction effects				
	Maximum contaminant level violations		Monitoring and reporting violations	
	coef	irr	coef	irr
Private	-0.283 (8.29)**	0.754	0.292 (7.22)**	1.339
Native American	0.013 (0.12)	1.013	1.733 (17.93)**	5.657
Federal	-0.384 (3.05)**	0.681	0.63 (4.95)**	1.877
State	-0.227 (2.04)*	0.797	0.229 (1.71) <sup>+</sup>	1.257
Income	0.002 (1.24)	1.002	0.009 (3.43)**	1.009
Share county urban	-0.296 (4.80)**	0.743	-0.202 (2.69)**	0.817
HHI (scaled 0–1)	0.329 (4.41)**	1.39	0.302 (3.16)**	1.353
Small	-0.278 (7.78)**	0.758	-0.538 (13.49)**	0.584
Medium	0.021 (0.45)	1.022	-0.576 (9.89)**	0.562
Large	0.296 (5.37)**	1.344	-0.439 (6.22)**	0.644
Very large	-0.396 (1.92) <sup>+</sup>	0.673	-0.68 (4.77)**	0.506
Water source=GUP	-0.824 (2.15)*	0.439	-0.876 (1.92) <sup>+</sup>	0.417
Water source=GW	0.427 (3.07)**	1.532	-1.114 (8.53)**	0.328
Water source=GWP	-0.107 (0.67)	0.899	-2.1 (13.97)**	0.122
Water source=SW	-0.425 (2.89)**	0.654	-0.734 (5.29)**	0.48
Water source=SWP	-0.609 (4.19)**	0.544	-2.033 (15.01)**	0.131
Constant	-2.641 (2.70)**		-0.701 (1.16)	
Observations	323,907		323,907	
Log likelihood	-84,466.765		-286,183.38	
LR chi <sup>2</sup> (230)	6394.58		23,801.17	
Prob>chi <sup>2</sup>	0.0000		0.0000	

Year and CBSA fixed effects included.

Absolute value of *z* statistics in parentheses.

Standard errors adjusted for within-system correlation.

<sup>+</sup>Significant at 10%; \*significant at 5%; \*\*significant at 1%.

larger systems for handling the costs of SDWA compliance. The table shows that more urban areas tend to have fewer violations, but that wealthier counties tend to have more violations. This latter result is surprising, but the regressions also control for CBSA fixed effects and urbanization, which are both correlated with income. It is also possible that EPA- and state-sponsored programs

intended to aid “small and disadvantaged” communities with respect to SDWA regulations are effective.<sup>28</sup>

#### 4.3. Results — interactions and simulations

The results presented above do not allow us to compare ownership types within size categories. To do so, we estimate the same negative binomial regression with ownership and size interaction effects. As above, we present both the estimated coefficients and the incident rate ratios, but it is difficult to determine their economic magnitude because negative binomial and Poisson regression coefficients are inherently difficult to interpret and because the interaction effects make even interpreting the IRRs challenging. To facilitate interpretation, we use the coefficient estimates to simulate the expected number of violations by ownership type and size category.<sup>29</sup>

Table 5 shows the results of estimating the equation with these interaction terms. Fig. 1 shows the simulated number of violations based on the regression results along with 95% confidence intervals around the point estimate. We simulate the expected number of events using the statistically significant coefficient estimates and setting the insignificant coefficients equal to zero, reflecting the regression’s inability to reject the hypothesis of that being the true coefficient estimate.<sup>30</sup> From the statistically significant coefficients we simulate the number of violations by ownership and size by setting the appropriate dummy variables equal to one,<sup>31</sup> the location fixed effects and the HHI equal to their population-weighted means, and water source and year fixed effects equal to their means. The results thus show the simulated number of violations for each ownership-size category, with the location, concentration of water systems, water source, and year being those of a “typical” system. The predicted number of violations would increase or decrease depending on actual location, water source, and year. The differences between the ownership categories, however, would not change.

#### 4.4. Contaminant violations

The first column of Table 5 shows the regression results while the first column of Fig. 1 shows the simulation results for maximum contaminant level violations. The simulations make clear that health-based violations are relatively rare for a typical water system, regardless of its ownership. The difference between private and locally-owned systems is generally quite small. Nonetheless, controlling for water source, location, income, the percentage of the population that is urban, the concentration of ownership in the local water market (as captured by our HHI) and year fixed effects, locally-owned water systems have more contaminant violations per year than privately-owned systems in all size categories except among very large systems, where the locally-owned systems have fewer violations per year. While the ownership effects in the regressions are statistically significant, the standard errors are large enough that the 95% confidence intervals in the simulations overlap. In other words, while the coefficients are statistically significant, their

<sup>28</sup> See <http://www.epa.gov/safewater/dwsrf.html>. Last accessed 03/15/05.

<sup>29</sup> We use the ‘prvalue’ ado program written by Long and Freese (2003) for these calculations.

<sup>30</sup> For the simulations we include coefficients significant at the 15% significance level or higher. While this is somewhat unconventional, it allows the simulation to include more variables. As it turns out, using only the statistically significant coefficients for the simulations slightly affects the level of the predicted number of events, but not the differences between ownership types.

<sup>31</sup> For example, for small private systems, private=1, size\_small=1, private\*small=1, all other size and ownership dummies=0.

Table 5  
Ownership, competition, and SDWA violations

With interaction effects				
	Maximum contaminant level violations		Monitoring and reporting violations	
	coef	irr	coef	irr
	(z-stat)		(z-stat)	
Private	−0.329 (8.19)**	0.72	0.356 (6.40)**	1.427
HHI (scaled 0–1)	0.325 (4.34)**	1.383	0.292 (3.07)**	1.339
Small	−0.337 (7.09)**	0.714	−0.475 (7.91)**	0.622
Medium	−0.061 (1.05)	0.941	−0.5 (6.80)**	0.606
Large	0.267 (4.28)**	1.306	−0.388 (4.69)**	0.678
Very large	−0.554 (2.59)**	0.574	−0.515 (3.38)**	0.598
Private*small	0.102 (1.51)	1.108	−0.164 (2.08)*	0.849
Private*medium	0.245 (2.29)*	1.278	−0.199 (1.60)	0.82
Private*large	−0.082 (0.56)	0.921	−0.126 (0.66)	0.882
Private*very large	0.727 (1.53)	2.069	−1.044 (2.35)*	0.352
Constant	−2.58 (2.63)**		−0.794 (1.36)	
Observations	323,907		323,907	
Log likelihood	−84,435.656		−286,139.4	
LR $\chi^2(243)$	6456.80		23,889.14	
Prob> $\chi^2$	0.0000		0.0000	

Year and CBSA fixed effects included in all regressions.

County, size, water source, and other ownership-size variables excluded from the table for brevity, but are included in the regression.

Absolute value of  $z$  statistics in parentheses.

Standard errors adjusted for within-system correlation.

\*significant at 5%; \*\*significant at 1%.

magnitudes do not imply an economically significant difference between ownership types. Thus, we cannot be confident at the 95% level that any given ownership type will be associated with more or fewer maximum contaminant level violations than other ownership types.

#### 4.5. Monitoring and reporting violations

As discussed above, states report each water system's number of monitoring and reporting (MR) violations to the EPA. These may indicate a system's effort to comply with SDWA regulations. They may also provide some indication of the cost required to comply with the regulations. While the EPA does not consider monitoring and reporting violations to be direct health threats, an MR violation may in some cases mask a more serious violation that does endanger public health.

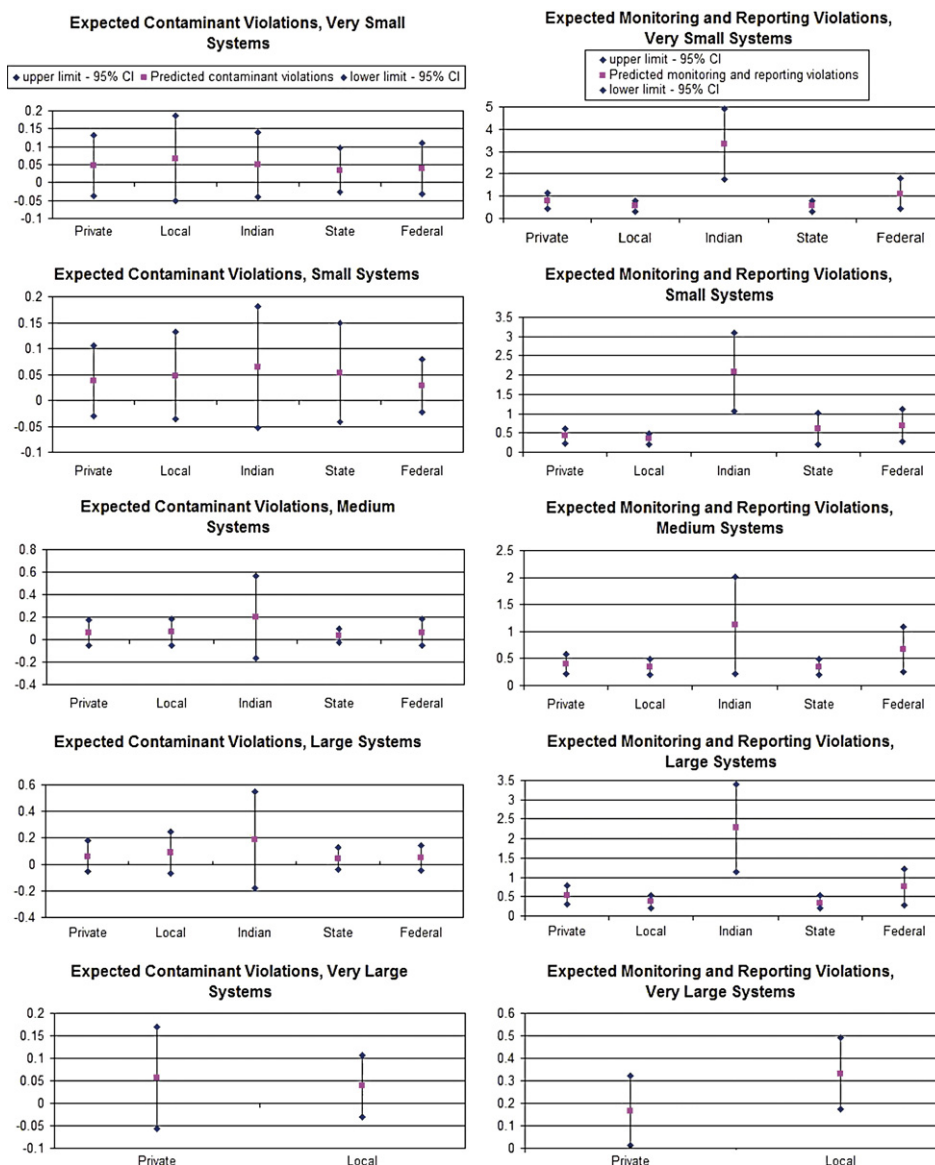


Fig. 1. Simulated number of violations.

The second column of Table 4 reports the results of estimating the regression where the dependent variable is the number of MR violations in a system-year while the second column of Fig. 1 shows the simulation results for MR violations. The first apparent result is that the predicted number of MR violations is about 10 times larger than the predicted number of contaminant violations. Among “very small” through “large” water systems, privately-owned systems have somewhat more MR violations than do systems of the same size owned by local governments. Very large local systems, however, have more MR violations than do very large private systems.

Just as in the maximum contaminant level simulations, the standard errors from these simulations are large enough that many of the 95% confidence intervals in the simulations overlap.

The results also suggest that Native American systems may be more likely to violate MR regulations than systems of other ownership type. This result is particularly apparent among very small, small, and large systems, where the confidence intervals of Native American systems are higher and do not overlap with those of private, local, or state-owned systems. Thus, for these system sizes, we can be confident at the 95% level that Native American systems have more MR violations than these other three ownership types. Similar statements cannot be made at the 95% level for other size and ownership types because of the overlapping of the confidence intervals.

#### 4.6. Benchmark competition

We are also interested in how the varying concentration of water systems (our measure of benchmark competition) affects regulatory compliance. Tables 4 and 5 show that violations are generally decreasing in competition. We use the coefficient estimates from Table 4 to simulate the changes in violations as benchmark competition changes because here we are not interested in the ownership-size interactions, and the results are otherwise largely identical. For these simulations, we hold the significant control and ownership variables constant at their weighted means (so, for example, the private ownership variable is set equal to 0.1518, reflecting the fact that about 15% of the population gets water from private systems). We then allow the HHI to vary from 200 (approximately the smallest value in the dataset) to 10,000 (indicating one system serving the entire county).

Fig. 2 shows the results of this simulation. The predicted number of contaminant violations increases from 0.035 in the most “competitive” counties to 0.049 in completely monopolistic counties. The predicted number of MR violations increases from 0.38 in very competitive counties to 0.51 in counties with a monopoly supplier. As in the ownership analysis, these are not tremendous differences, but do suggest that systems subject to benchmark competition have fewer violations.

The evidence on benchmark competition is, much like the phenomenon itself, indirect. To explore it a bit more, we add another measure of competition. The EPA makes all violations data public, regardless of system size. As discussed above, regulators have access to and are likely to know how to use EPA’s online data system to compare neighboring systems, which makes our HHI indicator a valid indicator of benchmark competition for regulators. Consumers, however, are much less likely to know of, let alone know how to use, the EPA’s data retrieval system. They

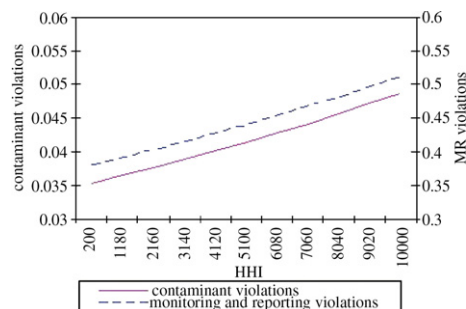


Fig. 2. Simulated number of annual SDWA violations by concentration of water systems in a county.

are more likely to read inserts in their bills that detail testing results and, when there is a violation, possibly be curious about nearby systems.

To proxy for this form of benchmarking, we count the number of water systems in the county – other than the observed system – that serve more than 100,000 people. Those systems are required to make certain water quality results easily available on their websites, thus making it easier for consumers – even those not served by that system – to see the results. We also interact that variable with a dummy indicating whether the observed water system serves at least 10,000 people, because those systems must inform their own consumers of certain SDWA test results. This interaction thus identifies water systems whose consumers are more likely than the average consumer to have knowledge of their system’s water quality and how it compares with that of neighboring systems.

Table 6 shows the results with these additional variables. They suggest that the number of large systems in a county is correlated with the number of contaminant and MR violations for systems that serve fewer than 10,000 people, though the coefficient on contaminant violations is not statistically significant. The coefficient on the interaction term is negative and significant in both equations, suggesting that when consumers have facilitated access to their own system’s SDWA reports, benchmark competition may have a robust impact on a system’s compliance with regulated water quality standards.

Table 6  
Ownership, competition, and SDWA violations

	Maximum contaminant level violations		Monitoring and reporting violations	
	coef	irr	coef	irr
	(z-stat)		(z-stat)	
Private	−0.307 (9.55)**	0.736	0.296 (7.29)**	1.345
Native American	0.008 (0.07)	1.008	1.729 (17.91)**	5.635
Federal	−0.391 (3.11)**	0.677	0.627 (4.94)**	1.872
State	−0.228 (2.05)*	0.796	0.232 (1.72) <sup>+</sup>	1.261
HHI (scaled 0–1)	0.306 (4.09)**	1.358	0.282 (2.92)**	1.326
Num other systems in county	0.006 (1.43)	1.006	0.01 (2.71)**	1.010
(Num other systems in county) * system serves > 10,000 people	−0.007 (1.91) <sup>+</sup>	0.993	−0.008 (2.68)**	0.992
Constant	−2.665 (2.72)**		−0.723 (1.2)	
Observations	322,851		322,851	
Log likelihood	−83,943.889		−285,114.89	
Wald chi <sup>2</sup> (232)	21,477.55		12,977.78	
Prob > chi <sup>2</sup>	0.000		0.000	

Size, water source, county control variables, and fixed effects not shown.

Year and MSA fixed effects included.

Robust z statistics in parentheses.

<sup>+</sup>Significant at 10% level; \*Significant at 5% level; \*\*Significant at 1% level.

Subtle differences in the contaminant and MR violations results add support to the benchmarking hypothesis. As we have measured it, benchmarking seems to be stronger for contaminant than for MR violations. The coefficient on the number of other systems in a system's county that serve more than 100,000 people is positive but not significant for contaminant violations, while the interaction term is negative and significant. In addition, the magnitude of the interaction term is larger than the coefficient on the base variable measuring the number of other large systems. Conversely, in the MR equation, the coefficient on the number of other large systems is significantly positive, and the coefficient on the interaction term is significantly negative. The magnitude of the interaction term is smaller than on the number of other large systems variable. In other words, by this measure, benchmarking appears to be stronger for contaminant level violations and weaker (or nonexistent) for MR violations.

One explanation for this result is that while water systems must inform consumers of contaminant violations, they are not required to inform consumers about MR violations. Thus, it is sensible that we would see a stronger effect on contaminant violations than on MR violations if benchmarking occurs. Given the disclosure rules, these results further support the benchmarking hypothesis.

At first glance, it appears puzzling that the HHI indicator would show benefits of benchmarking even for MR violations if utilities are not required to report them to consumers. It is important to note, though, that even MR results are posted on the EPA's website, meaning that regulators and others who work closely with the industry are likely to see those data even when consumers do not.

## 5. Discussion and conclusions

Despite the bitter controversy over privatization of water systems, this analysis finds little *ceteris paribus* difference between private and public water systems in regulatory compliance. Privately-owned systems report somewhat fewer contaminant violations than do locally-owned systems, but somewhat more monitoring and reporting violations (which, as discussed, may simply be a way of masking contaminant violations). For systems that serve more than 100,000 people, the results are reversed: private systems have more contaminant violations but fewer monitoring and reporting violations than do locally-owned systems.

While ownership, *per se*, does not appear to matter much here, the evidence suggests that benchmark competition makes some difference. We find that water systems in counties in which each water system tends to serve a smaller share of the county population have fewer violations. Likewise, regulatory compliance with respect to contaminant violations is better when water systems are required to disclose test results to consumers and consumers can easily compare performance to nearby systems. That is, SDWA compliance appears to be better in geographic areas in which it should be easier to compare one's utility to neighboring utilities with similar characteristics. The result is bolstered by the empirical finding that the effects of benchmarking are weaker on compliance with monitoring and reporting violations — violations that are far less visible to consumers.

Overall, the results paint a less dramatic picture than either opponents or proponents of private ownership argue. Neither ownership type consistently performs better than the other — on average, both private and local systems in the United States comply equally well with drinking water regulations. And, while some have argued that for small water systems, private firms may be better suited to handle the complicated and costly SDWA regulations (Koorse, 2001), the data do not suggest that small private systems are notably better or worse than small public systems.

Privately-owned water systems do not, of course, operate independently of government. States regulate investor-owned water systems, overseeing rates, investment, and profits (Beecher, 2000; Committee on Privatization of Water Services, 2002). It is possible, for example, that very large private systems have fewer monitoring and reporting violations in part because of strict regulatory oversight. For example, the California Public Utilities Commission regulates only investor-owned water and sewerage utilities, leaving municipalities to self-regulate their own local systems.<sup>32</sup> Our county fixed effects have mitigated the associated empirical problems to some extent, but more research is needed on how local and state policies affect the industry.

## 6. Caveats and conclusions

The results are intriguing, but data limitations prevent us from answering related, relevant questions and answering definitively whether one type of ownership is superior. First, the private sector can be involved in piped water provision in many ways besides outright ownership, including franchising, lease contracts and concessions, build-operate-transfer contracts, and maintenance contracts (e.g., Seidenstat, 2003). Different types of public–private interactions may create different incentives that could affect outcomes. Second, our data do not permit an analysis of efficiency. We have no information on operation costs, employment, or actual prices.<sup>33</sup> Without such information, it is not possible to directly estimate net welfare effects. Third, we do not observe the severity of contaminant violations and therefore the expected health harms that might result from them. As a result, we are unable to incorporate the real health consequences of violations into our analysis. Even a single violation of some contaminants could cause substantial health problems, while multiple violations of other contaminants grouped into the “health-based” category may have little or no impact on public health.

That public water systems differ so little from private water systems is sensible. Competition drives innovation and efficiency improvements, but in the water sector competition is not as robust as in other industries. Municipalities that contract out part or all of their water systems to private operators may create competition for the contracts, and the sheer number of water utilities suggests that there may be some benchmark competition. Even this limited form of competition appears to yield some benefits. The number of violations decreases as benchmark competition increases. The results suggest that privatization debates may be misplaced. Rather than focusing on ownership, *per se*, regulators and policymakers should focus on ways of increasing competitive pressure.

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<sup>32</sup> See <http://www.cpuc.ca.gov/static/industry/water/index.htm>. Last accessed March 9, 2005.

<sup>33</sup> We analyzed data on household expenditures separately. That analysis, which yields results similarly supportive of benchmark competition, is available online.

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