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Status Report on:

How Small is Too Small? Scale Economies in Water Utilities

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ABSTRACT

New York State faces a pressing challenge due to aging and inadequate drinking water infrastructure, such as pumps, plants, and pipes. Public resources to address this issue are limited. To be effective, water policy must consider the key concept of *economies of scale*, or how water's cost varies with the size of the providing firm. If water systems are too small, so that larger size would reduce the cost per gallon, there may be social benefits from increasing scale by consolidating two or more firms. We estimate scale economies in U.S. water infrastructure by examining the effect of firm size on the price per gallon, which we take as a proxy for unit cost. We collected data on U.S. water systems for the years 2004, 2006, 2008, 2010, and 2012 to produce 1,371 unique firm-level observations. Preliminary estimates using this large data set indicate that there are substantial economies of scale in water utilities, suggesting that the customers of some water systems in New York would benefit from consolidation.

Key Points:

- Understanding economies of scale in water, i.e. how cost varies with the size of the firm, is critical for using scarce public resources wisely
- This research uses the largest data set yet assembled to study economies of scale in U.S. water utility systems
- Preliminary estimates indicate substantial economies of scale in U.S. water utilities, but not so in the Northeastern utilities

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Aging, leaking, and inadequate water infrastructure is one of the most pressing challenges currently facing New York State. Many of the State's water and sewer pipes, pumps, and plants were installed decades ago and are longl past their original design lives. Addressing this challenge requires substantial new investment. According to one estimate, maintaining New York's wastewater infrastructure alone will cost more than $30 billion over the coming decade.

Given the stresses on public budgets, policies toward water infrastructure must ensure that the greatest value is realized from every dollar spent renovating the State's water infrastructure. A key factor in achieving that goal is understanding the best size of a water or sewer system, as well as the institutional arrangements that either promote or inhibit movement toward that size. The firm's size in the long run (i.e. when it can adjust all its inputs) is referred to as its *scale*.

Effective New York State water policy must therefore reflect the key concept of economies of scale in the production of both water and sewer services. Economies and diseconomies of scale refer to the phenomenon that the unit cost (or "average cost") of producing a good varies with the size of the firm in question. For most industries, unit cost first declines, levels off, and then rises with firm size. In the context of urban water delivery, the cost per gallon of drinking water delivered to a household will decline – up to some point – as the number of households served grows larger.

This effect is usually attributed to the high fixed costs associated with installing the system necessary for the production and delivery of clean water. The point at which the unit cost of production ceases to decline as a firm gets larger is called the firm's *minimum efficient scale*. The concept of minimum efficient scale has important implications for public policies toward water infrastructure, such as Smart Growth. It also helps address the critical policy question in water provision of "how small is too small?" That is, when does a water utility become so small that it loses the social benefits of scale economies?

Scale economies in water infrastructure are a critical factor in understanding how to <u>maximize the social return</u> from investments in such infrastructure. This is important since many water systems in New York are old and are likely to be replaced in the upcoming decade. Suppose there are two adjacent, small municipalities that each operate their own water system. That arrangement may result in substantial waste, as they may each be operating at inefficiently low output – and consequently high resource cost – relative to what could be achieved through one larger system. If the two systems were to combine, that may result in large social gains through enhanced scale economies. If so, then the individual systems are "too small" by this definition. We stress that since there is little-to-no overlap between the adjacent municipalities' service areas, it is premature to claim that physical consolidation in water utilities will always result in increased efficiency without further empirical analysis. The minimum efficient scale concept applies to both publicly owned treatment works (POTWs) and to privately operated treatment works, so its policy implications are broad.

Water utilities in New York are administered at the local level, attributed largely to the State's "home rule" governance structure. The utilities are required to provide an annual compliance report to the NYS Department of Health, which includes results of water quality tests conducted at regular intervals throughout the year. However, there is no requirement to provide information on water rates to any state agency, or even make it available on their respective websites.[1] As a result, it is difficult to ascertain rates charged by New York water utilities. We focus instead on water utilities across the U.S. and provide here a progress report on efforts to estimate scale economies in U.S. water utilities. We first describe the foundation of those efforts: the water utility data set. We then present preliminary results and a brief discussion. We then discuss public outreach and student training associated with these efforts.

Data

The core of this research is the water utility data set. An unusually large data set on U.S. water systems has been collected and organized. The main data source for information on U.S. water utilities comes from the American Water Works Association (AWWA) *Water and Wastewater Rate Survey* for various years. These surveys of AWWA members are conducted every two years and contain information on a large number of water systems. For example, the 2012 survey provided for 290 water utilities and 214 wastewater utilities from 44 states and the District of Columbia. Utilities included represent a wide range of firm sizes, from those serving between 1,000 and 9 million customers. The survey includes a number of variables, covering many aspects of water and wastewater operations in the systems sampled. The AWWA survey covers both public and private utilities but is skewed towards the former.

We relied on an initial compilation of AWWA rate survey data provided by Mr. David Gordon of HDR Engineering, Inc. That initial set contained data for the years 2004, 2006, and 2008 on several hundred variables about U.S. water systems. We extended that data set to include 2010 and 2012. This allows us to form a panel data set of water utilities across time. There are 1,371 observations when all years and systems are included in the data set.

Our analysis uses a larger and more recent data set than the previous studies of this issue. For example, Shish et al. (2006) use data from the Community Water System Survey (CWSS) for their study of economies of scale in water infrastructure. Their data set incorporates only 2 years: 2000 and 2006. Several other researchers have used data from a single year to address various questions related to the effect of rate structure and firm ownership on water demand (Bhattacharyya et al., 1995; Nieswiadomy and Cobb, 1993; Sohn, 2011; Teodoro, 2009) In contrast, our data on water utilities comes from five surveys conducted by the American Water Works Association (AWWA) through 2004 and 2012. This was combined with data gathered from three surveys conducted by the National Association of Water Companies (NAWC). Our analysis has the potential of incorporating data from <u>all</u> *Water and Wastewater Rate Surveys* conducted by AWWA from 1996 to 2014.

In addition to a larger sample of water utilities from across the country, we incorporate a much larger set of explanatory variables in our models. Most of these variables were already present in the AWWA surveys while others were created using the data available. Consequently, we

[1] Private water companies are required to inform the New York State Public Service Commission (NYSPSC) of their current rates, and seek permission to modify them. Therefore, a catalog of rates charged by private water providers is available at the NYSPSC website. Private providers constitute a small fraction of the total water suppliers (and serve a small fraction of the population) across the state, hence such data will be highly biased and not representatitive.

control for numerous factors in addition to scale that might influence water rates and help explain variation in water rates. A more detailed discussion of the variables in the data set is provided in Appendix A.

The expanded set in both years and variables will allow us to more precisely estimate the effect of firm size on our measure of unit cost (the per-gallon rate), and thus scale economies in both water and wastewater systems.

The processes of providing drinking water and treating wastewater differ greatly. We thus divided the sample into systems that provide drinking water, wastewater treatment, and both combined. This allows us to determine if scale economies differ significantly across the three system types. We also divide the data set based on the jurisdiction relevant for that utility (e.g. city, district, county, private or other). This also allows us to observe how economies of scale differ according to jurisdictional lines, assuming that sufficient observations are available for a given jurisdictional type.

Preliminary Results & Discussion

Although the data are not yet ready for full estimation of economies of scale using sub-samples, preliminary estimates of the effect have been computed and are reported in the appendix. We consider economies of scale by estimating the effect of firm size (measured by millions of gallons per day, or MGD) on the average residential and commercial rate. AWWA surveys provide tiered rates for each consumption block, but we only present results for typical monthly consumption – 1000 cu.ft for residential and 3000 cu.ft for commercial users.[2] We present two models in each case – (a) with year-fixed effect, and (b) with year- and city-fixed effects. Fixed effects (FE) models control for variation observed across any particular variable. Preliminary estimates are reported in Appendix B.

These estimates indicate that, controlling for jurisdictional type, firm size has a significantly negative effect on water rates. This is consistent with firms benefitting from economies of scale over certain ranges of output. The coefficient of elasticity is -0.038 in Model 1, i.e., a 10 percent reduction in the volume of water sold (MGD) results in a 0.38 percent increase in water rate. In addition, utilities with higher per-unit water rates also maintain a higher debt portfolio, have lower employee productivity, are publicly-owned and are administered by a county or district authority, and located in the Northeast. Model 2 includes city fixed effects (i.e. a set of binary variables for each city) and therefore drops independent variables that are time-invariant in any particular city. The size effect becomes less significant and less elastic in model 2. Employee productivity is also not significant.

The estimates for commercial rates are similar to those observed in residential rates (Table 6). Both models include only time fixed effects; no city fixed effects are included. Model 2 includes additional variables on ground water and purchased water. Utilities that source a smaller fraction of their supply from groundwater sources and those that purchase a greater fraction from other neighboring utilities have higher water rates.

[2] 1,000 cu.ft = 7,500 gallons or 28,000 liters (approx.)

Table 7 presents estimates for residential rate for the Northeast region. The dataset includes 147 utilities. Since only a few utilities from New York are included in our dataset, patterns observed in the Northeast are a close approximation. Similar to Table 6, both models include only year fixed effects. High debt ratio, low employee productivity, administration by county or a district authority, and low use of ground water and purchased water is associated with higher rates. Contrary to observations in the national residential and commercial rate models, the size effect disappears in Northeastern water utilities. The effect of ownership type on rates is weak and only observed in one of the models.

Analysis of the national dataset suggests that water utilities do not discriminate significantly between residential and commercial users. There is, however, a regional effect: rates in the Northeast are much higher than the other regions. We also observe significant economies of scale in U.S water utilities. However, that effect is not manifested in the Northeast utilities. The data will need to be carefully parsed to observe any outlier effect due to the presence of large utilities like those in the cities of New York, Boston and Philadelphia on the model estimates. Hence, these estimates can only be taken as being suggestive. We plan to add additional independent variables that incorporate city-specific characteristics such as area, density, and median income, and climate characteristics such as mean annual temperature and precipitation. The inclusion of additional explanatory variables will make our estimates more robust and conclusive. We further intend to conduct a similar analysis for wastewater rates by the utilities.

Overview of Outreach

Regarding public outreach, several activities will be undertaken to ensure that research findings are accessible to the wider public. Research findings will be disseminated widely through peer-reviewed papers, workshops and conferences, media availability, and announced on social media (such as Twitter). Also, a substantial web presence dedicated to global infrastructure policy issues is maintained through the Cornell Program in Infrastructure Policy (CPIP). CPIP allows the posting of working papers related to infrastructure policy issues on its web site.

Student Training

This research has resulted in intensive training in the collection, organization and cleaning of an extensive data set for two Cornell students: Renee Botelho and Kushagra Aniket. Others, such as Andre Gardiner, benefitted form background research on infrastructure policy issues. Students have benefited from extensive interaction with two PhD-level researchers in this area, Prof. Rick Geddes and Dr. Sri Vedachalam.

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Appendix A: Discussion of Dependent and Explanatory Variables in the Data Set

Dependent Variables

Water Rates

The main dependent variable examined water rates charged to users. Utilities from 47 states and the District of Columbia were included in the survey. Utilities charge different rates for residential and nonresidential consumers depending on the level of water consumption (measured in cubic feet (cf)), as below:

Residential

1. Rate1: 0 cf
2. Rate2: 500 cf
3. Rate3: 1000 cf
4. Rate4: 1500 cf
5. Rate5: 3000 cf

Nonresidential

1. Rate6: Non-Manufacturing/Commercial (3000 cf)
2. Rate7: Commercial/Light Industrial (50,000 cf)
3. Rate8: Industrial (1,000,000 cf)
4. Rate7: Industrial (1,500,000 cf)

Seasonal rates: Some utilities charge higher rates during peak usage periods to incentivize conservation. In such instances, I have considered the off-peak rates for this analysis.

Rate3 is regarded as the average residential rate. Rate6 is regarded as the average commercial rate. These two rates serve as the dependent variables in our models.

The rates were adjusted for inflation by taking 2004 as the base year and using the following adjustment factors:

Table 1: Inflation adjustment

Year	Adjustment Factor
2006	0.94
2008	0.88
2010	0.87
2012	0.82

Source: CPI Inflation Calculator, Bureau of Labor Statistics

Explanatory Variables

There are several explanatory, or independent, variables, included in the data set.

Utility Size

The size of water utilities can be measured by a number of variables such as:

1. Daily Gallons Sold (DGS) measured by the gallons of water sold in million gallons per day (MGD). DGS was calculated from the annual data for the most recent reporting year for every survey.
2. Average Daily Water Production
3. Service Population
4. Daily Production Capacity
5. Maximum Daily Production

AWWA classifies water utilities into three groups on the basis of daily gallons sold. Small utilities (Group C) produce less than 20 MGD, medium utilities (Group B) produce between 20 and 75 MGD, and large utilities (Group A) produce greater than 75 MGD. Overall, the monthly water charges were generally lower for the Group A and B utilities than the Group C utilities, reflecting the benefits of economies of scale.

However, we chose Daily Gallons Sold (DGS) as the measure of size for our analysis for reasons of consistency and data availability.

Ownership

AWWA classifies the ownership of water utilities into several categories:

1. City or Municipality
2. District or Authority
3. County
4. Investor-owned or Private
5. Other

However, the majority of the water utilities in the survey are municipal utilities.

In those cases where we did not have any documentation for ownership classified as "Other", we had to drop the entries from our dataset. Adding that to the utilities for which ownership was not recorded in the surveys, we had 28 missing entries in the column on ownership.

Productivity Ratio

The productivity ratio is a measure of the efficiency of a utility. It is computed as the ratio of DGS to the number of full-time employees. The productivity ratio also reflects the labor intensiveness of a utility.

Debt Ratio

Operating expenses and debt constitute the bulk of costs for most utilities. The debt ratio is calculated as the ratio of total long-term debt to total assets. The higher the debt ratio the more a utility has to borrow to pay for its capital needs. Consequently, the debt ratio is hypothesized to be an important driver of water rates.

Census Regions

We include dummies for the four Census Regions in our model: Northeast, Midwest, South and West.

Other Independent Variables

Other independent variables that could be incorporated in a further study are:

1. Climate information: annual temperature, rainfall, drought index
2. City specific characteristics: population density, median income and size of the city

Water source: percentage from groundwater, surface water and purchased water

Appendix B: Preliminary Estimates

Table 2: Summary Statistics on Basic Variables

Variable	N	Min	Max	Mean	Std. dev.
Residential rate (Rate3)	1281	0.82	36.79	7.25	4.54
Commercial rate (Rate6)	1304	8.35	300.20	58.15	25.92
Daily Gallons Sold (MGD)	1298	0.01	1266.96	49.18	102.83
Debt Ratio	1127	0.0006	1.34	0.31	0.20
Daily Gallons Sold per Employee (MGD)	1229	1.19e-5	20.57	0.32	0.68
% Ground Water	1199	0	100	31.93	41.36
% Purchased Water	1199	0	100	15.07	32.40

Note: We use the logarithmic transformations of the following variables in our model:

1. Rate3
2. Rate6
3. Daily Gallons Sold
4. Debt Ratio
5. Daily Gallons Sold per Employee

Categorical Variables

Table 3: Region

Level	N
Midwest	263
Northeast	147
South	568
West	393
Total	1371

Table 4: Ownership

Level	N
Investor-owned or Private	32
City or Municipality	951
County	71
District or Authority	289
Total	1343

Table 5: Regression estimates for residential rates

Variable	Model 1	Model 2
Year Fixed Effects?	Yes	Yes
City Fixed Effects?	No	Yes
Intercept	3.162*** (55.41)	3.274*** (31.96)
Log (Daily Gallons Sold)	-0.038*** (-4.24)	-0.056* (-1.82)
Log (Debt Ratio)	0.098*** (8.67)	0.053*** (4.49)
Log (Daily Gallons Sold per Employee)	-0.142*** (-7.43)	-0.001 (-0.06)
Investor-owned or Private	0.223*** (4.03)	
City or Municipality	-0.107*** (-4.36)	
County	-0.049 (-1.18)	
Midwest	-0.105*** (-4.88)	
Northeast	0.076*** (2.88)	
South	-0.799*** (-4.65)	
N	997	1013
R^2	0.276	0.928

Note: Dependent variable is log (Rate3). Parameter estimates are coefficients (t-statistics in parenthesis).

* Indicates significant difference from zero at the 10 percent confidence level using a two-sided test.

** Indicates significant difference from zero at the 5 percent confidence level using a two-sided test.

*** Indicates significant difference from zero at the 1 percent confidence level using a two-sided test.

Table 6: Regression estimates for commercial rates

Variable	Model 1	Model 2
Year Fixed Effects?	Yes	Yes
City Fixed Effects?	No	No
Intercept	3.95*** (62.74)	4.01*** (57.66)
Log (Daily Gallons Sold)	-0.013 (-1.31)	-0.026** (-2.55)
Log (Debt Ratio)	0.082*** (6.53)	0.074*** (5.76)
Log (Daily Gallons Sold per Employee)	-0.192*** (-8.85)	-0.268*** (-9.41)
Investor-owned or Private	0.159*** (2.63)	0.227*** (3.75)
City or Municipality	-0.099*** (-3.70)	-0.122*** (-4.36)
County	0.42 (0.42)	0.008 (0.16)
Midwest	-0.118*** (-4.97)	-0.077*** (-3.24)
Northeast	0.108*** (3.69)	0.086*** (2.95)
South	-0.045** (-2.37)	-0.041*** (-2.15)
% Ground Water		-0.002*** (-6.09)
% Purchased Water		0.003*** (6.23)
N	993	882
R^2	0.247	0.321

Note: Dependent variable is log (Rate6). Parameter estimates are coefficients (t-statistics in parenthesis).

* Indicates significant difference from zero at the 10 percent confidence level using a two-sided test.

** Indicates significant difference from zero at the 5 percent confidence level using a two-sided test.

*** Indicates significant difference from zero at the 1 percent confidence level using a two-sided test.

Table 7: Regression estimates for residential rates in Northeast region

Variable	Model 1	Model 2
Year Fixed Effects?	Yes	Yes
City Fixed Effects?	No	No
Intercept	3.220*** (16.52)	3.399*** (15.90)
Log (Daily Gallons Sold)	-0.023 (-0.81)	-0.024 (-0.80)
Log (Debt Ratio)	0.111** (2.32)	0.080* (1.69)
Log (Daily Gallons Sold per Employee)	-0.231*** (-2.66)	-0.199** (-2.23)
Investor-owned or Private	0.229 (1.41)	0.331* (1.94)
City or Municipality	-0.245** (-2.06)	-0.350*** (-2.96)
County	0.262 (0.80)	0.332 (1.03)
% Ground Water		-0.003** (-3.04)
% Purchased Water		-0.003** (-2.190)
N	109	100
R^2	0.266	0.342

Note: Dependent variable is log (Rate3_NE). Parameter estimates are coefficients (t-statistics in parenthesis).

* Indicates significant difference from zero at the 10 percent confidence level using a two-sided test.

** Indicates significant difference from zero at the 5 percent confidence level using a two-sided test.

*** Indicates significant difference from zero at the 1 percent confidence level using a two-sided test.