Journal of Environmental and Resource Economics at Colby

Volume 4 | Issue 1 Article 6

2017

Water Restrictions and Water Use: An Analysis of Water Restriction Effects in Norfolk County

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Cover Page Footnote

We would like to thank Professor Nathan Chan for his assistance with this research project.

1. Introduction

Water is essential to all living things, but the lack of water is a growing concern across the globe. Water scarcity impacts at least 2.8 billion people around the world for at least one month a year, and the ability to access water is not always guaranteed (The Water Project, 2016). As a result, many environmental protection agencies have implemented water restrictions within the United States to reduce the occurrence of water shortages. These policies either voluntarily or mandatorily ask individuals to reduce water usage on a daily, weekly, or monthly basis. While the prevalence of restrictions has increased in past years, the success of such restrictions in reducing water usage has not been studied comprehensively in this context before.

In July of 2016, the National Drought Mitigation Center, a drought monitor partnership with the University of Nebraska-Lincoln, designated one-third of Massachusetts under the “severe drought” classification. To reach this threshold, towns had to have seen fewer than five inches of rainfall compared to past years’ standard. Furthermore, the Office of Energy and Environmental Affairs illustrated that this was only the second time in history that the classification had been used in Massachusetts (Wang, 2016). As a result, the number of policies addressing water usage has increased within the past five years. Currently, Massachusetts’ primary mechanism for combating the decline in accessible water is the implementation of water restrictions. These restrictions fall under one of two categories: mandatory or voluntary. Additionally, within each general category of restriction type, there is a wide range of restrictions used. Such restrictions may be every even or odd day, every other week, etc. However, only the category of the restriction is reported, therefore, we generalized the type of restriction by category.

Having an adequate supply of water has always been a concern for the residents of Massachusetts. Consequently, this concern led to the creation of the Quabbin Water Reservoir, a man-made reservoir built in the 1930s with a 412 billion gallon water capacity (MacNeill, 2016). Today, the water flows from the Quabbin Water Reservoir to the John J. Carroll Water Treatment Plant, which started ultraviolet disinfecting and adding sodium hydrofluorosilicic acid for dental health and other treatments beginning in October 2013 (Carroll, 2013). From there, the water goes through tunnels underground serving over 2.3 million people in Massachusetts. Together, these systems are the backbone of how the roughly 690,000 individuals of Norfolk County have access to water. Within the past years, the frequency of droughts has decreased the water supply in the Quabbin Reservoir. In August 2016, the reservoir reportedly lost ten billion gallons within the month, thus emphasizing the need to find an effective way to decrease municipal water consumption (Metzger, 2016).

The goal of this paper is to identify whether there is a statistically significant impact of water restrictions, both voluntary and mandatory, on municipal water usage in the Norfolk Country of Massachusetts. Additionally, we will examine the impacts of voting preferences, average precipitation, and average temperature on water usage for each town within Norfolk County.

We develop a two-tailed hypothesis in which the presence of a water restriction in a town will have a significant effect on municipal water usage. On one hand, the presence of a water restriction might result in a decrease in water use in that town. This is based off of previous literature showing that water restrictions are effective at reducing water usage in North Carolina (Kenney, 2004). On the other hand, however, the structure of water restrictions might incentivize people to use more water on days that restrictions are not in place, so water use may increase overall as a result of a restriction.

2. Literature Review

Given the growing awareness of environmental matters due to projects such as Al Gore's documentary, *An Inconvenient Truth*, environmental conservation approaches have become an increasingly popular topic. In particular, water usage has garnered a substantial amount of attention due to severe water shortages and extreme droughts, the most recent and notable case being California's five-year drought. Existing literature on droughts focuses on numerous different tactics to decrease usage, including pricing schemes and behavioral and social motivations for decreasing use (Brent, Cook, & Olsen, 2015).

Despite the increased attention, there are a limited number of studies specifically focusing on water restrictions and water usage. One study by Kenney, Klein, and Clark (2004) examines drought conditions and water restrictions in cities along Colorado's Front Ridge Area. During the summer of 2002, the Denver metro area was hit with an unexpected and extreme drought. This forced the city to sanction both mandatory and voluntary water restrictions on its residents for the entirety of the season. These authors study the magnitude of the water restrictions' effect on water usage as well as the difference in effectiveness of the type of restriction used. They found that mandatory restrictions resulted in a substantial but wide range of water savings from 18 to 56 percent savings per capita. These savings greatly overshadowed those under the voluntary water restrictions, which resulted in water savings of 4-12 percent. Kenny et al.'s (2004) work provides us with evidence of the efficacy of water restrictions for decreasing water usage in times of drought.

In a similar manner, studies on the 1977 droughts in Iowa and Colorado yielded results mirroring those of Kenney et al.'s work (Lee, 1981; Anderson, Miller, & Washburn, 1980). In both Iowa and Colorado, the year of 1977 marked a severe water shortage due to droughts. Consequently, mandatory and voluntary restrictions were put into place as an effort to combat the shortage. Not only did these sets of authors find significant results showing that water restrictions are an effective way at reducing water use, but they also found that mandatory restrictions were more successful than voluntary ones.

The most recent and perhaps most relevant research about water restrictions looks at the effects of water restrictions on water usage in North Carolina's Research Triangle (Wichman, Taylor, and von Haefen. 2016). These researchers found that price mechanisms had a heterogeneous effect across income distributions for reducing water usage; lower income households were more sensitive to price changes and reduced water usage more as a result of a price change than higher income households. However, these authors additionally found that water restrictions had a uniform effect on water usage across incomes. The Research Triangle encompasses towns that are similar politically to those of Norfolk County, thus this research served as a large motivation for our own research.

This paper seeks to add to the small but growing amount of literature on the use of water restrictions and water usage reduction. In addition to these four studies, it seems that the majority of the current literature is mainly focused on the 1970s and 1980s. More specifically, these studies also do not span a period of more than one year. The water restrictions in Norfolk County not only encompass a geographic area not heavily studied, but they also are in place over the course of multiple years. These circumstantial differences in extant literature and our study demonstrate how our study can contribute important results to this existing field of economic research.

3. Data

We compile data from the Massachusetts Department of Environmental Protection under the Executive Office of Energy and Environmental Affairs, which includes both the start and end dates of each water restriction. The data we use span 27 towns for the years 2012- 2016. Within each year there are five months (May, June, July, August, September) studied. The data also contains the total number of water restrictions by town as well as the type of restriction. The municipal water usage is obtained from the same department as the water restriction data, with the assistance of Jen D'Urso from the Water Management Act Program in MassDEP's Boston office. This data is reported as monthly averages of municipal water usage of gallons per person per day by each town.

Furthermore, we use data capturing political voting trends to examine if the political identity of a town affects responses to water restrictions. Collected from the Massachusetts Election Results for 2016 and accessed through Bostonglobe.com, the data is coded based on the percentage of the town that voted for the democratic, republican, or other political party candidate during the past presidential election in November of 2016. Along with this, we merge weather data summarizing monthly averages and rainfall in order to evaluate variations in weather across towns, which could potentially impact water consumption. Weather data is obtained from wunderground.com, a site that contains both real-time and historical data about weather in different towns.

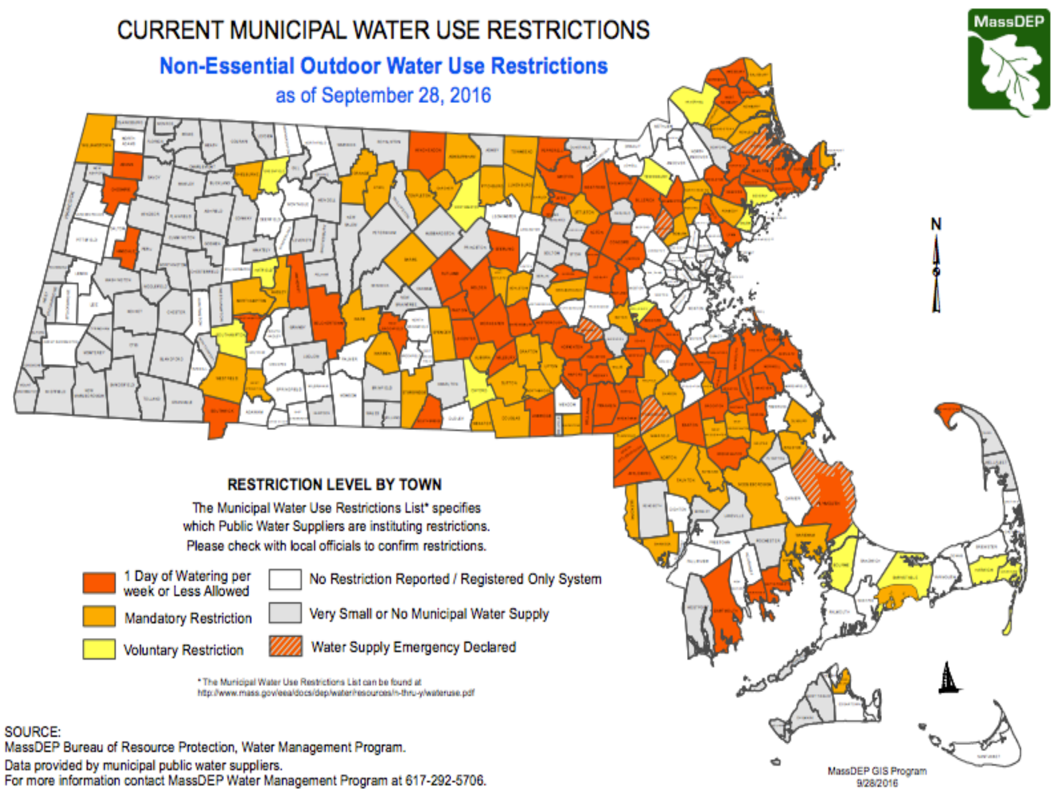

Figure 1. Municipal water use restrictions active in September 2016 (*source: http://www.mass.gov/eea/agencies/massdep/water/watersheds/municipal-water-use-restrictions.html)*

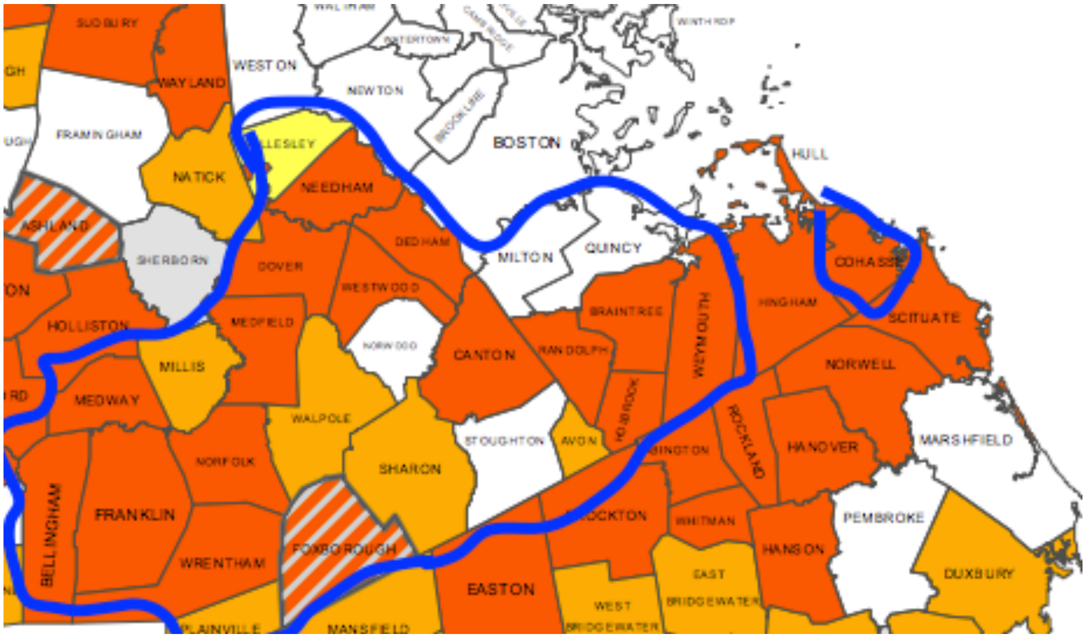

Figure 2. Zoomed in view of Figure 1, outlining the towns within the Norfolk County, Massachusetts (*source: http://www.mass.gov/eea/agencies/massdep/water/watersheds/municipal-water-use-restrictions.html*)

Together, this produces 675 total observations with a single observation considered as the month-year-town explanatory restriction and the outcome of water usage, thus the resolution of our data is monthly. However, after going through the raw data, we had to remove any observations that were missing values for any of the variables, thus we have a final total of 664 total observations with an unbalanced panel.

The data is panel data, as there is time series data within the town comparing across months and years, and cross sectional data comparing across towns in the Norfolk County. When examining voting trends there is no inter-temporal data, but there is cross sectional variation across towns. Additionally, fixed effects are added in our regression to encompass anything time invariant within a town.

Table 1 shows summary statistics and variable descriptions. With three towns that always have restrictions in place and three towns that never have restrictions, these towns serve as control towns in our data.. When the regression is conducted, these towns are omitted because of multicollinearity. Outcome Usage is the average water consumption within a given town in gallons per person per day from 2012 to 2016. Restriction is a binary variable that reflects the frequency that a restriction was implemented within a given town.

Table 1. Summary statistics, all towns in Norfolk County, with and without water restrictions.

Town	Outcome Usage	Restriction	Avg. Rainfall	Avg. Temp.
Avon	55.28	.28	.08	65.08
Bellingham	75.44	.80	.08	65.08
Braintree	67.28	.08	.11	66.88
Canton	68.92	.44	.09	66.24
Cohasset	77.46	.50	.07	67.00
Dedham	68.68	.64	.11	66.88
Dover	75.52	.80	.09	66.24
Foxborough	70.68	.80	.09	66.24
Franklin	54.12	.64	.08	65.08
Holbrook	53.92	.08	.08	65.08
Medfield	87.28	.44	.09	66.24
Medway	77.36	.92	.09	66.24
Millis	68.16	1.0	.09	66.24
Milton	74.35	0.0	.08	65.15
Needham	9.52	.60	.09	66.24
Norfolk	61.64	.80	.09	66.24
Norwood	59.88	0.0	.09	66.24
Plainville	59.45	.25	.08	65.15
Quincy	45.60	0.0	.08	65.08
Randolph	64.60	.08	.08	65.08
Sharon	60.84	.92	.09	66.24
Stoughton	72.48	0.0	.09	66.24
Walpole	85.44	1.0	.09	66.24
Wellesley	81.04	.28	.09	66.24
Westwood	68.88	.44	.09	66.24
Weymouth	58.60	.08	.08	65.08
Wrentham	71.12	1.0	.09	66.24
Total	68.29	.48	.09	65.94

4. Method

A standard Ordinary Least Squares regression is used to estimate the unit change in gallons per person per day of municipal water usage in two difference-in-difference models. First, each town is examined on an individual basis, such that the town is evaluated before and after a restriction is implemented. The following regression framework is used to evaluate this:

$$waterusage = \alpha + \beta_1 rest.ever + \beta_2 rest.current + \beta_3 avgprecip. + \beta_4 avgtemp + \beta_5 democrat + \beta_6 republican + \beta_7 otherpolitical + \epsilon$$

where β_1 represents the value change in gallons per person per day for municipal water usage within a town that has had a restriction implemented at any point in time from 2012-2016. The β_2 value is the same units as β_1, except that it is if the restriction is currently active within a given town, and the regression also includes a stochastic error term. If no restriction was ever implemented in the time frame, then those towns are used as controls and are used to establish any other trends that the model may not account for directly. For example, maybe there was a new study published that revealed a high demand of water for agriculture then previously believed. Another potential confounding aspect may be that school systems did not end until late in a particular year, so less water was used for outdoor activities because children were still in school. By using the restriction ever term, we can establish that the model will control for any confounding variables that may impact a given town across the years studied. Then, the restriction current variable can explicitly analyze the water usage before and after a restriction is implemented within a given town.

Secondly, we run a fixed effects regression to evaluate the estimates of water usage with the presence of water restrictions and no restriction. The fixed effect was coded based off town with Avon as the first town.

$$waterusage = \gamma_1 rest.current + \gamma_2 avgprecip. + \gamma_3 avgtemp + \gamma_4 democrat + \gamma_5 republican + \gamma_6\ otherpolitical + FE + \epsilon$$

Similar to the model 1 equation, β_1 represents the same as β_2 with the value representing the change in water usage in gallons per person per day when the restriction is currently implemented. In model 2, we include fixed effects to control for individual town effects.

Lastly, we run another fixed effects regression similar to model 1 and 2, to determine if there is a difference between the voluntary and mandatory restrictions. This can be analyzed with a regression of the following form:

$$waterusage = \beta_1 mandatory + \beta_2 voluntary + \beta_3 avgprecip + \beta_4 avgtemp + \beta_5 democrat + \beta_6 republican + FE + \epsilon$$

5. Results

Table 2 summarizes the initial regression results of model 1 within each town for all variables correlated with the outcome variable of municipal water usage by town. What's interesting about these results is that the variable "*restrictionever*", meaning if there was any type of water restriction at any point in a given town, is positive. This could be interpreted as saying that the type of town that implements a water restriction naturally uses more water to begin with. We found that when a town implements a water restriction there is a statistically significant 6.25 gallons increase per person per day in water consumption. This positive and statistically significant result appears to support the hypothesis that individuals are incentivized to consume more water on days that a restriction is not implemented to compensate for the upcoming restriction, increasing overall water consumption.

Table 2. Standard regression model 1 results.

VARIABLES	(1) Model 1
rest.ever	6.351***
	(1.400)
rest.current	1.794*
	(1.007)
avgprecip	23.09***
	(6.129)
avgtemp	0.00860
	(0.0823)
democrat	-0.760***
	(0.196)
republican	-1.167***
	(0.207)
constant	145.1***
	(19.45)
Observations	664
R-squared	0.148

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

If we conclude our findings just from regression 1, we would find a positive relationship such that when towns implement a water restriction, there is an increase in municipal water usage. However, further analysis is necessary, as there might be other factors influencing the findings, such as town effects.

To determine if this positive coefficient was due to the model not capturing factors that account for differences between towns, we estimate a second model, shown in Table 3, this time accounting for town fixed effects. Without including the fixed effects, the towns may have been influenced by other factors than just the restriction, for example some towns may have a higher baseline demand for water or have a less elastic demand and/or supply for municipal water usage compared to other towns surveyed within this study. The exclusion of fixed effects would under-bias our results.

Table 3. Standard regression model 2 results with fixed effects.

VARIABLES	(1) Model 2
rest.current	-2.621***
	(0.758)
avgprecip	18.25***
	(3.718)
avgtemp	-0.0341
	(0.0498)
democrat	-7.795***
	(1.374)
republican	-7.642***
	(1.968)
Observations	664
R-squared	0.703

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Standard regression model 3 results for mandatory and voluntary restrictions with fixed effects.

VARIABLES	(1) Model 3
mandatory	-2.628***
	(0.793)
voluntary	-1.450
	(1.356)
avgprecip	18.29***
	(3.810)
avgtemp	0.0485
	(0.0511)
democrat	-6.957***
	(1.425)
republican	-6.671***
	(2.045)
constant	701.5***
	(160.5)
Observations	663
R-squared	0.688

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

After conducting a regression with fixed effects, we find that implementing a water restriction within a given town in the Norfolk County results in a statistically significant decrease in water consumption by 2.62 gallons per person per day. These results support the initial hypothesis that there is a significant effect of water restrictions on water use in Norfolk County and that the direction of this relationship is negative.

The results from model 3, which differentiates by type of water restriction, show that the mandatory restrictions have a statistically significant effect on decreasing water usage, but that there is not statistically significant effect of this with voluntary restrictions. This supports previous literature's findings about the importance of mandatory restrictions over voluntary ones.

Additionally, when a town's average voting preference is either more democratic democratic or more republican, the town experiences a decrease of roughly 7.5-8 gallons per person per day. This negative correlation between when a town has a current restriction implemented and municipal water usage supports the other tail of our hypothesis. Overall, after accounting for individual town effects we conclude that when a town has an active water restriction there is a statistically significant decrease in municipal water usage at the 1% level by 2.6 gallons per person per day.

6. Conclusion

With the advent of many weather extremes throughout the United States and the world, more research on how to effectively and efficiently combat these changes is necessary. Previous research has shown that water restrictions, especially mandatory ones, are effective strategies for decreasing water usage. These past studies focus on the Midwest region of the United States and do not encompass droughts and water restrictions longer than a year. This paper evaluates the effects of water restrictions on municipal water usage over the span of five years in Norfolk County, MA. The results indicate that the use of water restrictions is followed by an overall decrease in water usage. It is implied that even within the same county, towns can vary considerably because this negative correlation was only found when accounting for town fixed effects.

As with any type of research, there are challenges and limitations to address with this study. One challenge with studying water restrictions is accounting for their visibility. If some towns are better than others at publicizing when and what type of water restriction is in place, our results may not be representative of this. Another facet to consider is the enforcement of water restrictions. Depending on how strongly the restrictions are enforced and the severity of violations, it can be hard to measure the actual effectiveness of the water restrictions. Future research should try to account for the differences in publicizing the restrictions and their enforcement. This will allow for a more comprehensive analysis of the effectiveness of water restrictions and may even point to ways in which they could be made even more useful.

References

Anderson, R. L., Miller, T. A., & Washburn, M. C. (1980). Water savings from lawn watering restrictions during a drought year, Fort Collins, Colorado. *JAWRA Journal of the American Water Resources Association*, *16*(4), 642-645.

Brent, D. A., Cook, J. H., & Olsen, S. (2015). Social comparisons, household water use, and participation in utility conservation programs: Evidence from three randomized trials. *Journal of the Association of Environmental and Resource Economists*, *2*(4), 597-627.

Carroll, J., (2013) "Quabbin Reservoir" *John J. Carroll Water Treatment Plant*.

Chang, A., & Carroll, M. (2016) "Map: Massachusetts water usage and cost, by town" *Department for Environmental Protection for Usage, Tighe & Bond inc. Boston.com*.

D'urso, J. (2017) "Water restriction by town, Massachusetts" *Massachusetts Department of Environmental Protection, Executive Office of Energy and Environmental Affairs*.

Kenny, D., Klein, R., & Clark, M. (2001) "Use and effectiveness of municipal water restrictions during drought in Colorado". *Journal of the American Water Resources Association*.

Lee, M. Y. (1981). Mandatory or voluntary water conservation: a case study of Iowa communities during drought. *Journal of Soil and Water Conservation*, *36*(4), 231-234.

MacNeill, A., (2016) "Drought Killing Ipswich River wildlife, forcing water restrictions across region" *The Salem News*.

Metzger, A., (2016) "Quabbin remains within normal range despite losing 31 billion gallons" *Boston Neighborhood News, Inc*.

Mini, C., Hogue, T., Pincetl, S. (2013) "The effectiveness of recent water restriction policies on single-family water use in Los Angeles, California" *American Geophysical Union*.

Tighe & Bond. (2016). "MA sewer and water survey"M*assachusetts Department of Environmental Protection (MassDep)*.

(2014) "Water Use Data for Massachusetts" *National Water Information System: web interface: USGS*.

Wichman, C., Taylor, L., & von Haefen, R. (2016). Conservation policies: Who responds to price and who responds to prescription? *Journal of Environmental Economics and Management, 79*(C), 114-134.