THESIS

POLICIES VERSUS PERCEPTION: ESTIMATING THE IMPACT OF DROUGHT AWARENESS ON RESIDENTIAL WATER DEMAND

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Spring 2011

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ABSTRACT

POLICIES VERSUS PERCEPTION: ESTIMATING THE IMPACT OF DROUGHT AWARENESS ON RESIDENTIAL WATER DEMAND

In response to the water shortages of 2002, Colorado utilities adopted numerous policies promoting water conservation. However, despite this demand-management emphasis, utilities are still distinguishing between the impacts of conservation programs and the psychological impacts of the drought itself. That is, water managers are unsure if post-drought decreases in water consumption are solely due to utility-controlled policies or if they result from a combination of drought awareness and/or permanent changes in water-use behaviors. For this reason, gauging the effectiveness of conservation policies requires answering the following: First, did awareness of the drought lead consumers to conserve more water than predicted, given utility policies alone? Next, if drought awareness did influence demand, is continued awareness--as opposed to utility policies or permanent changes in water use—the reason water demand has failed to return to pre-drought levels? To answer these questions, this research estimates an econometric water demand model using billing data from a major Colorado utility. Results show that drought awareness did decrease water demand both during and after the height of the drought; however, baseline demand still appears to be trending downward even after we control for both drought awareness and utility policies.

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I. INTRODUCTION

As Colorado's most-recent experience with widespread water shortages, the summer of 2002 marked a turning point for municipal water managers. The drought, fostered by record-setting dry conditions from spring through fall of 2002, forced utilities to abandon traditional, supply-side approaches to water provision in favor of an emphasis on demand management. This was especially true for the largest water providers in the Front Range, who launched a bundle of watering restrictions, price increases, and incentive programs in a massive effort to decrease water consumption.

The cumulative effect of drought-related conservation policies is that water demand in some Colorado utility service areas fell upwards of 30% between 2002 and 2009. As such, numerous studies have attempted to quantify the impacts of the individual conservation policies that contributed to this overall consumption decrease. This work includes forthcoming research sponsored by the Colorado Water Conservation Board on the potential for conservation-based water savings, as well as previously-published articles on effectiveness of water restrictions (Kenney, et al, 2004) and of demand management programs in Aurora, CO (Kenney, et al 2008). However, despite this focus on the impact of drought-related policies, little research has examined how the drought itself—a natural disaster that, like any other, could be expected to have a psychological effect on consumers--impacted water use. For this reason, utilities throughout the Front Range are still trying to distinguish between the impacts of these policies and the short and long-term psychological impacts of the drought itself. That is, water managers are unsure if decreases in water consumption seen since 2002 are solely due to utility-controlled policies, or if they are attributable to a combination of drought awareness and/or drought-induced permanent changes in baseline water consumption.

The above-mentioned questions are important because uncertainty regarding the impact of drought makes it difficult for utilities to understand how a “typical” consumer uses water. For example, if observed water savings are the result of the “drought shadow effect,” meaning ongoing drought awareness, then the amount of water used by consumers once we account for all measurable variables—in other words, baseline demand-- has not changed. Thus, consumers might be expected to increase their water consumption again once they forget about the drought and/or policies are phased out, so failing to account for these effects could cause utilities to underestimate future required water supplies (See Figure 1). Similarly, if this short-term response to drought awareness is large, there could be a trade-off between using conservation campaigns between droughts (decreasing consumers’ baseline water usage) and achieving crisis-based decreases in demand during severe water shortages. Lastly, separating the impacts of policies and awareness from changes in baseline demand is important because water providers need to know if the drought experience caused a fundamental change in how Coloradoans use water, via both adoption of water-saving behaviors and use of more water-efficient technologies. Nevertheless, though utilities say they believe water use is “different” from what it was before 2002, the water literature lags behind energy and other fields in examining psychological influences on consumption behavior.

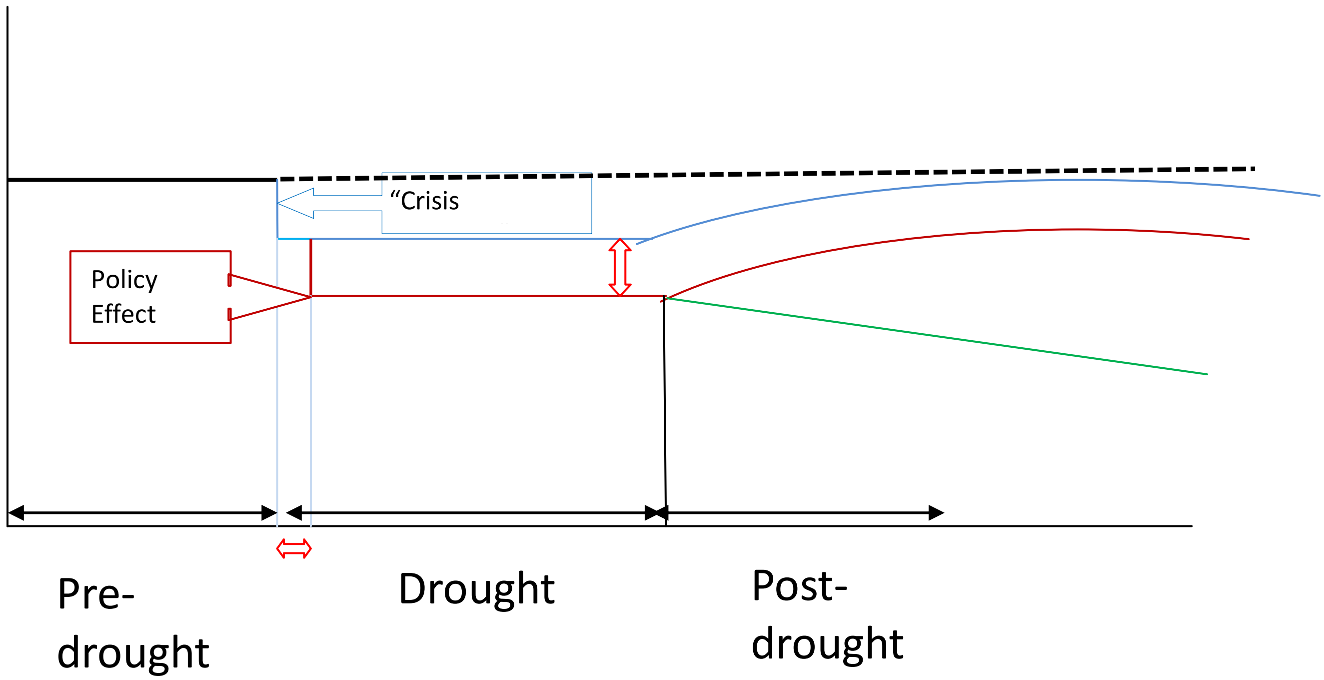

Figure 1: The Impact of Drought on Water Demand

As pictured, awareness of the drought/perception of a water crisis may induce some consumers to conserve voluntarily, meaning they decrease their water demand even before the utility implements conservation programs (*blue*). Next, further decreases in demand occur when conservation programs are put into place (*red*). In the post drought period, demand may rebound if policies are phased out and/or consumers no longer perceive there to be a crisis. On the other hand, if the drought experience leads to permanent changes in water use behavior and induces consumers to use more water-efficient devices, baseline water demand may remain at lowered levels or even continue to fall (green).

Though utilities want to know if water demand is fundamentally “different” now from what it was before 2002, the water literature lags behind energy and other fields in examining psychological influences on consumption behavior. Despite the water literature’s lack of research integrating economics and psychology, however, researchers in other fields—principally energy--have developed models of consumer behavior during shortage events, meaning when (and what types of) consumers can be expected to perceive a crisis and respond to it.

With regards to consumers’ noticing a crisis, Billings (1980) used survey work and energy use data from a natural gas shortage in Ohio and found that perception of crisis depends upon one’s noticing a difference between “the standard and the existence state.” To be perceived, a “crisis” must be seen as more severe than some “threshold” specific to that consumer. This threshold is partly determined by an individual’s “probability of loss” (will the crisis affect him?) and “response uncertainty” (does the consumer believe his actions can help solve the problem?). Additionally, perception of a crisis is also a function of utility policies that alert the consumer to the event, and it is unclear whether it is policies themselves or resulting awareness that leads to behavior changes (Jorgensen 2009). Taken together, this research would mean Colorado consumers could be expected to curb their short-term water use if drought-related news and/or policies caused them to view the 2002 drought as a new problem with relevance to their daily lives. Furthermore, some consumers may buy new water-saving appliances/devices that lead to permanent changes in water use.

Second, to make things more complex, the worldview that drought is a problem is in itself a function of a consumer’s past experience with shortages. For example, Weinsten (1989) examines research on natural disasters and finds that people generally assume a disaster will have the same level of severity/magnitude as those experienced previously, so individuals who experienced greater harm are more likely to take preventive action in the future. In Colorado, this could mean that people who are told there is a drought crisis and feel the effects of drought-related policies may be more likely to turn short-term responses to drought into permanent water-conserving behaviors—in essence, drought and conservation could become the new "norm." Within the water demand literature, this finding is echoed by Verdugo, et al (2000) and Campbell, et al (2004), who studied water use in Mexico and Arizona, respectively, and found that consumers familiar with water shortages and/or who had previously lived in drought-prone states were more likely to have a "conservation ethic."

Though familiarity with drought may make consumers conscious of the need for conservation, the duration of this "conservation ethic" is debatable. In evaluating the energy shocks of 1973-1983, Ritchie and McDougall (1985) find that consumers respond to crises in "pre-decision" and "post-decision" stages. After deciding to conserve in the "pre-decision" stage, the consumer re-evaluates that decision and often increases his energy usage in order maintain the pre-crisis standard of living. Similarly, in a report on the California Energy Crisis of 2001, Goldman, et al (2002) concludes that, while crisis awareness spurred up to 75% of that year's total energy load reductions, "It is much less clear the extent to which these changes will persist over the long-term, because it depends in part on customers' continuing perception of electricity or other energy crises[.]" (p. 25). This ambiguity mirrors that seen by Colorado utilities, which are unsure if decreased demand witnessed since the 2002 drought is the result of ongoing drought awareness, utility policies, or a move toward a permanent "conservation ethic."

Next, it should be noted that perception of a crisis/response to shortages will vary across municipalities, as different "types" of consumers are likely to react to utilities' short-term water conservation campaigns. For instance, Berck et al (1993), used survey data from Los Angeles and San Francisco, California, from 1986-1991 and found that those who believed conservation was more "socially desirable" had higher (self-reported) levels of water conservation. On the other hand, in tying water use data to surveys of residents in New Hampshire, Hamilton (1983) found that individuals with pro-conservation beliefs generally had higher incomes and used more water than the general public. As a result, even though these individuals reduced their usage during drought, reductions were offset by these users' high pre-shortage water consumption. Taken together, these opposite findings highlight the fact that water savings depend not only upon consumers' willingness to conserve, but also upon their ability to do so, given the amount of indoor and outdoor water already being used. Furthermore, other studies (Di Leo 2003; McKenzie-Mohr, et al 2000) have found that beliefs have little impact on consumer water use in comparison with habits, meaning even conservation-minded individuals won't save very much water if they aren't induced to change ingrained water use behaviors. Lastly, to add to all this uncertainty, none of these studies attempted to measure consumers' long-term response to conservation campaigns, and no work (that we know of) has examined how a consumer's general awareness of drought alters his water consumption in either the short or long terms.

So, what does all of this mean for Colorado utilities? In accordance with this previous research, it is not drought itself, but awareness, perception, and attitudes regarding drought that determine how a water shortage impacts consumer behavior, both in absence of and in conjunction with utility policies. Based on the literature above, this means that utility policies (especially those with a monetary impact) and social awareness of drought could have led consumers to see a difference between "the standard and the existent states"; furthermore, if drought-created behaviors became the new "norm," the 30% reduction in water use seen in areas of Colorado since 2002 could be partially attributable to a fundamental change in how consumers use water or to installation of water-conserving appliances. Though without additional data, it is impossible to tell if consumers now use more water-efficient technologies in their homes, we can derive research questions from the above-mentioned literature with regards to the impact of drought awareness on water demand as follows:

First, *did social awareness (measured in terms of news coverage) of drought impact short-term water demand, and does failure to account for awareness change estimates of the impact of other policies?*

Secondly, *in accordance with literature that says consumers only perceive a "crisis" if they feel its effects, do some types of awareness (meaning news articles about drought-related policies versus news on the general need for conservation) have more of an impact on demand than others?*

And lastly, *is there still difference in pre- and post-drought baseline water demand once short-term drought awareness and utility policies are controlled for—i.e., could the drought have instilled a type of "conservation ethic" (related both to permanent behavioral changes and adoption of water-saving technologies) in consumers for Colorado water providers.*

II. ECONOMETRIC MODEL

The above-mentioned research questions can be answered by estimating three related econometric models: a baseline model, a model that controls for drought-related news, and a model that includes separate variables for different types of news. As seen below, the baseline model is a basic water demand model that, holding time-invariant variables constant, estimates water use for household *i* at time *t* as a function of utility policies (restrictions and average prices) and control variables. "Post-Droughtyr" variables then capture the difference in baseline demand seen in each year during and after the start of the drought[1], as compared to the pre-drought period.

Baseline Model

$$\begin{aligned} lnw_{it} = \alpha + \beta_1 \ln\left(avgprice_{t-1}\right) + \beta_2 restrict + \beta_3 PDroughtyr02 \\ + \beta_4 PDroughtyr03 + \beta_5 PDroughtyr04 + \beta_6 PDroughtyr05 \\ + \beta_7 PDroughtyr06 + \beta_8 PDroughtyr07 + \beta_9 PDroughtyr08 \\ + \beta_{10} PDroughtyr09 + B_{11} ControlVariables_t + \varepsilon \end{aligned}$$

[1] The defined "start" and duration of the drought depends upon the index used; for instance, the Colorado Climate Center considers the drought to last only from September 2001 to August of 2002, while the University of Nebraska, Lincoln "Drought Monitor" index does not peak until Spring/Summer of 2002 (and lasts throughout 2003). For this reason, dummy variables were included for each year during and after the earliest defined start of the drought (September 2001) so that changes in demand could be examined without defining a specific "drought" period.

Next, Model 1 is the baseline model with the addition of a variable to estimate the impact of drought awareness (measured in terms of drought-related news) on water demand; additionally, this model can be used to test the null hypothesis that there is no difference between pre- and post-drought water demand once utility policies and awareness are controlled for.

Model 1: Baseline Model + Drought Awareness Variable

$$\begin{aligned} lnw_{it} = \alpha &+ \beta_1 lnavgprice_{t-1} + \beta_2 restrict + \beta_3 PDroughtyr02 \\ &+ \beta_4 PDroughtyr03 + PDroughtyr04 + \beta_6 PDroughtyr05 \\ &+ \beta_7 PDroughtyr06 + \beta_8 PDroughtyr07 + \beta_9 PDroughtyr08 \\ &+ \beta_{10} PDroughtyr09 + \beta_{11} Droughtnews_{t-1} \\ &+ B_{12} ControlVariables_t + \varepsilon \end{aligned}$$

Specific null hypotheses for this model are as follows:

1) Social awareness had no impact on water demand ($H_{0:}$ β_{11}= 0).
2) There is no significant difference between demand in post-drought years compared to pre-drought demand, once drought water demand, drought awareness, utility policies, and weather are controlled for ($H_{0:}$ β_i= 0, where β_i are the drought year dummy variables. For example, the null hypothesis that demand in drought year 2003 is no different from pre-drought demand would be $H_{0:}$ β_4= 0).

Lastly, Model 2 includes drought news variables disaggregated into news related to price increases and restrictions (i.e., news on policies that cause the consumer to feel the effects of the drought) and news related to the drought and water conservation in general. The model also contains interaction terms, “Mrestrictnews” and “Vrestrictnews,” for restriction-related news immediately prior to and during the period when mandatory watering restrictions were in place (May 2002-September 2005) and news during the voluntary restriction period (October 2006-2009), respectively. This is done to control for the fact that restriction articles during the mandatory restriction period could have a varying effect on water demand—i.e., articles that talk about restrictions in the context of increases in allowable watering days or the permitted start of outdoor irrigation (which occurred annually in April) may actually increase water demand. By disaggregating drought-related news in this manner, the model can be used to test if all types of news have the same impact on water demand.

Model 2: Baseline Model + Drought Awareness Variable, disaggregated by type of news:

$$\begin{aligned} lnw_{it} = \alpha + \beta_1 lnavgprice_{t-1} + \beta_2 restictictions_t + \beta_3 Pdroughtyr02 \\ + \beta_4 PDroughtyr03 + \beta_5 PDroughtyr04 + \beta_6 PDroughtyr05 \\ + \beta_7 PDroughtyr06 + \beta_8 PDroughtyr07 + \beta_9 PDroughtyr08 \\ + \beta_{10} PDroughtyr09 + \beta_{11} Pricenews_{t-1} + \beta_{12} restrictnews_{t-1} \\ + \beta_{13} Mrestrictnews_{t-1} + \beta_{14} Vrestrictnews2_{t-1} \\ + \beta_{15}\ Conservenews_{t-1} + B_{16} ControlVariables_t + \varepsilon \end{aligned}$$

The null hypothesis is as follows:

1) All types of news have the same impact on water demand: H_0: $\beta_{11} = \beta_{12} = (\beta_{12} + \beta_{13}) = (\beta_{12} + \beta_{14}) = \beta_{15}$.
2) As in Model 2, this model can be used to test if there is a difference in pre- and post-drought baseline water demand after we control for awareness, policies, and weather.

III. DATA AND VARIABLES

a. Utility Policy Variables:

For the purpose of estimating these models, a large Colorado water provider provided billing data for all metered residences from 1998 to 2009. The data was cleaned to include only single-family households with a 5/8 (residential) tap size; furthermore, only households with a complete billing record (130 total bill periods across the period of study) were kept in the sample. Next, households that had participated in incentive programs--including rebates for water-efficient irrigation equipment, water-efficient toilets and showerheads—were also dropped from the dataset, as it would be impossible to tell if changes in water use for these water users result from behavioral change or installation of new water-efficient appliances. It should be noted, however, that households may purchase water-saving appliances without any incentives. Because we do not have the data to capture this effect explicitly, adoption of water-efficient appliances will be captured in the "post-drought year" dummy variables.

After cleaning the data in this manner, we were left with roughly 18,000 households with complete billing records, meaning the dataset contained over two million observations of consumers' monthly water bills (total bill and cubic feet of water consumed). To speed the estimation process, random numbers were assigned to each household, and subset of the data (roughly 9,000 households with complete billing records) was used to estimate the econometric models described previously. In addition to providing billing records, the water utility also provided detailed information on all conservation policies used over the period of study. In general, implementation of these policies coincided with the height of the drought in 2002; in July of that year, the utility instituted both mandatory watering restrictions and an increasing block water rate structure for summer months. Use of both voluntary and mandatory water restrictions continued in the post-drought period, and the block-rate structure became year-round policy on May 1, 2006. Additionally, water rates were raised throughout the period of study. Figure 2 and Tables 1-2 (below) detail use of price and restriction policies since 2002.

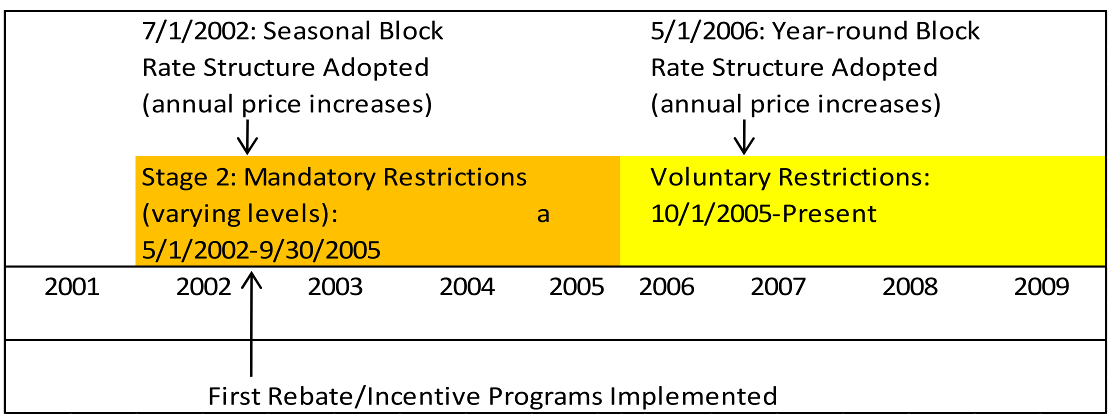

Figure 2: Timeline of Policies Used

Table 1: History of Watering Restrictions (days of watering allowed)

2002	2003	2004	2005	2006-2009
Summer: 5/1-6/10: Stage 1, Voluntary 6/11-8/17: Stage 2, 3/week 8/17-9/30: Stage 2, 2/week	Summer: 4/15-9/30: Stage 2, 2/week	Summer: 10/14: Stage 2, 2/week	Summer: 4/15-5/24: Stage 2 2/week 5/25-9/30: Stage 2, 3/week	Stage 1, Voluntary
Winter: 10/1/2002- 4/14/2003: Stage 2, 1 day/month	Winter: 10/1/2003- 4/14/2004: Stage 2, 1 day/week	Winter: 10/15/2004- 4/14/2005: Stage 2, 1 day/week		

Table 2: Pricing Policies

Date	Flate Rate/day	Charge/cf	0-999 cf	1000-2999 cf	>3000 cf
		Nov-April			
10/1/1998	$ 0.14	$ 0.01604			
6/1/1999	$ 0.14	$ 0.01673			
			Summer Block Rates		
7/1/2002	$ 0.14	$ 0.0152	$ 0.0152	$ 0.0191	$ 0.0227
2/1/2003	$ 0.17	$ 0.0155	$ 0.0155	$ 0.0215	$ 0.0250
2/1/2004	$ 0.18	$ 0.0169	$ 0.0169	$ 0.0263	$ 0.0309
1/1/2005	$ 0.19	$ 0.0179	$ 0.0179	$ 0.0278	$ 0.0330
Year Round Block Rates					
5/1/06 (1)	$ 0.1900		$ 0.0161	$ 0.0278	$ 0.0420
2/1/2009	$ 0.2820		$ 0.0221	$ 0.0410	$ 0.0615
1/1/2010	$ 0.3383		$ 0.0224	$ 0.0418	$ 0.0617

b. The Drought Awareness Variable:

As stated previously, drought-related news was used as a measure of the social awareness of drought for residents of the water provider studied here. As it is impossible to measure awareness of drought/perception of a crisis explicitly without survey work, the frequency of drought-related news is the best-available measure of how aware consumers were of the drought and drought-related policies at the time.

The drought news variable was constructed by using the archive search feature of "Google News" to record the frequency of drought-related articles that appeared in two major newspapers commonly read in the service area in question. Specifically, articles containing key words "Colorado drought" together with one of the terms "water rates," "water conservation" or "water restrictions" were collected by month from 2000 to 2010. The number of news articles varies each month across the drought and post-drought period; thus, though not a perfect measure of how aware consumers were of the drought, drought-related news serves as an indicator of social discourse on water shortages and how those shortages will impact consumers. For more detailed information on construction of the "drought aware" variable, see Appendix 1.

A comparison between the number of monthly drought-related articles and values of the "Drought Monitor," the National Drought Mitigation Center's drought index, can be seen in Figure 3. As seen, increases in the number of monthly articles coincide with the start of the drought, but seasonal (summer) increases in drought-related news continue after the drought index begins to fall in early 2003. Based on the literature, one would expect that consumers respond to awareness of water shortages—meaning drought-related news—rather than to the presence of a drought itself. Furthermore, because increases in articles are seen before utility policies are implemented in July of 2002, the separate impacts of awareness and policies can be estimated.

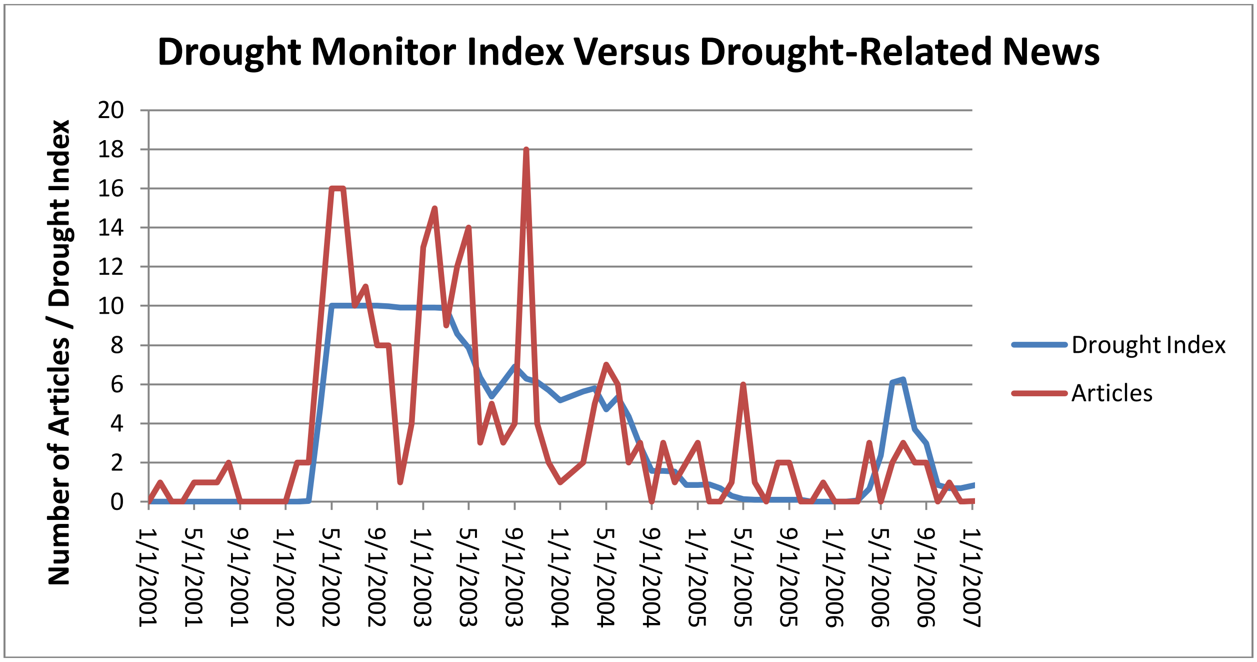

Figure 3: Drought Monitor Index versus Drought-Related News

IV. ECONOMETRIC SPECIFICATION AND METHODOLOGY

Coefficients for the above-mentioned variables were estimated using a fixed-effects instrumental variables econometric model that takes advantage of the panel data (total bill and water usage for residential customers) provided. The benefit to using the fixed effects method is that it measures changes in water use for individual household accounts relative to those households' average water use over the period of study. As a result, this method provides consistent parameter estimates of the time variant variables in the absence of household-level variables that determine water use, such as income and number of persons in the household.

Consistent with previous research, natural logarithms of the water consumption and average price (total bill divided by cubic feet of water consumed) variables were used in the regression; this log-log specification means estimates for these coefficients represent the (constant) elasticities for these variables. Instrumental variables is used to avoid potential bias caused by the endogeneity between price and water consumption that may occur with block-rate pricing structures (Hewitt and Hanemann, 1995). Additionally, a lagged value of the "droughtnews" variable was used to reflect the fact that changes in water use due to drought awareness do not affect the current bill, but the bill the customer receives the following month. Lastly, monthly and yearly dummy variables were included to capture seasonal trends in water use (more water is used during summer) and allow for comparison of baseline water use (after controlling for policies, weather, and drought awareness) across years.

Table 3: Variables

Variables	**Definition**	**Data Source**	**Expected Effect on Water Demand**
Lnlagp	Lagged value of average price/cubic foot of water	Colorado Springs Utilities (CSU)	Negative and inelastic--previous estimates average 0.6 (Arbues 2003)
Restrict	Dummy variable equal to 1 when mandatory water restrictions are in place	CSU	Negative; Kenney, et. al (2004) estimate 10-30% reductions in water use under 2002 restrictions
Droughtnews, pricenews, restrictnews, conservenews	Number of drought-related articles by month	Google News	Variables of interest
Bpdays	Number of days in bill period	CSU	Positive; More water used across a longer bill period
Totalprecip	Total precipitation during bill period	Colorado Springs Airport weather station	Negative
Avemxtemp	Average maximum temperature during bill period	Colorado Springs Airport weather station	Positive
unemrate	Monthly unemployment rate for Colorado Springs MSA	U.S. Bureau of Labor Statistics	Negative if downturn in economy lowers income
Month*	Monthly dummy variables; compare water use to January baseline		Water consumption should increase in summer months
PDrought Yr* (Variables for all Drought and Post-Drought Years)	Dummy variables for each year during and after the start of the drought, as defined by the Colorado Climate Center (September of 2001).		Variable of interest

V. RESULTS

Results for the three models are presented in Table 3 below. * Denotes results are significant at a 1% (or less) level of confidence.

Table 3: Results

Variables	Base Model Coefficients	Model 1: Aggregate Drought Aware Variable	Model 2: Awareness Variable disaggregated by type of news
Lnlagp	-0.2985*	-0.3072*	-0.3229*
Restrict	-0.0927*	-0.0536*	-0.0436*
Droughtnews	--------	-0.0019*	----------
Ratenews	--------	--------	-0.0112*
Restrictnews	-------	--------	0.0252*
-----Mrestrictnews	--------	--------	-0.0266
-----Vrestrictnews	--------	-------	-0.0657
Conservenews	--------	--------	-0.0004*
Bpdays	0.0378*	0.0376*	.0375*
Totalprecip	-0.0326*	-0.0317*	-0.0318*
Avemxtemp	0.0212*	0.0209*	0.0207*
Unemrate	-0.0180*	-0.0201*	-0.0210*
February	-0.0260*	-0.0237*	-0.0158*
March	-0.0849*	-0.0753*	-0.0761*
April	-0.0470*	-0.0428*	-0.0307*
May	0.2273*	0.2343*	0.2375*
June	0.2971*	0.3116*	0.3236*
July	0.2372*	0.2563*	0.2695*
August	0.1372*	0.1435*	0.1514*
September	0.1041*	0.1107*	0.1186*
October	0.0675*	0.0737*	0.0763*
November	-0.1153*	-0.1098*	-0.1114*
December	-0.0509*	-0.0512*	-0.0453*
Pdy2002	0.0289*	0.0452*	0.0506*
Pdy2003	-0.0487*	-0.0514*	-0.0622*
Pdy2004	-0.0277*	-0.0427*	-0.0450*
Pdy2005	-0.0408*	-0.0681*	-0.0656*
Pdy2006	-0.1197*	-0.1137*	-0.0765*
Pdy2007	-0.2607*	-0.2550*	-0.2364
Pdy2008	-0.1609*	-0.1531*	-0.1310*
Pdy2009	-0.1387*	-0.1261*	-0.1097*

Coefficients for all variables are significant and of the expected sign. Additionally, coefficients are consistent across models, with the exception of those for restrictions and the post-drought year dummy variables (estimates of price elasticity vary slightly across models, but this difference is not statistically significant). As seen, the coefficient for restrictions is significantly higher in Model 1 than it is in the other two models when we control for drought awareness. With regards to the drought-year dummy variables, Years 2002 and 2006-2009 are overestimated and Year 2003 slightly underestimated, respectively, when the drought-related news variables are not included in the model. Lastly, baseline water use is decreasing in all post-drought years except 2002, which is consistent with previous work that says baseline water use was actually increasing throughout Colorado until 2003 (Aquacraft, 2006).

In answer to the question, "*Did social awareness (measured in term of news coverage) of drought impact short-term water demand in Colorado Springs?*" the fact that the "Droughtnews" variable is negative and significant means we can reject the null hypothesis that drought awareness had no impact on water demand. Though the magnitude of this variable may at first appear small (approximately -0.002), spikes in the number of monthly articles (from only 2-4 to peaks of up to 18) occur frequently over the period of study, so the impact of drought awareness may be larger in some months. For instance, ten drought-related articles would decrease water demand by 2%. Furthermore, the fact that coefficients for the different types of news are significantly larger than the "droughtnews" coefficient as a whole may mean that consumers received mixed messages about the drought over the period of study. This idea is consistent with the result that the "Mrestrictnews" coefficient is much lower than that for "Vrestrictnews" which suggests that consumers may have read drought-related news--perhaps related to changes in allowable watering days and/or the start of the summer irrigation season--which induced them to increase water use during years 2002-2005. Similarly, mixed messages may also be captured by the "Conservenews" variable, as some articles that appeared after the height of the drought stress the need for conservation while also mentioning that precipitation had returned to normal levels (and even record levels by summer 2004).

Next, it should be noted that the coefficient for restrictions decreases by roughly half (from -0.09 to -0.04) once we control for drought awareness. This is evidence of omitted variable bias, meaning that, because presence of restrictions is correlated with drought-related news, the restrictions variable in Model 1 captures the effects both of restrictions themselves and the aggregate level of drought awareness at the time. This finding is consistent with the literature, which states that the overall impact of shortage-related policies is heavily dependent upon public perception of the problem (Joregenson, 2009); as an example, watering restrictions would have little impact on demand if consumers watered twice as long on allowable days. Furthermore, the very small magnitude for restriction-related news during the mandatory restriction period (roughly -0.001) is consistent with the idea that consumers who are already aware of (and reducing water use accordingly) restrictions will not be unable to decrease consumption further in response to restriction-related news.

Lastly, the results above show that failure to account for drought awareness can lead to biased estimates of baseline demand. In the results above, it appears that baseline water use would have been higher in 2002 if not for drought awareness. Furthermore, failing to include the drought policy aware variable appears to significantly decrease the magnitude of the 2003 drought year variables in Model 1; this is consistent with the idea that consumers received mixed messages after the height of the drought (allowable watering increased from 1 day/month to two days/week on April 15 of 2003). On the other hand, from 2006 onward--after mandatory restrictions are lifted--drought awareness makes a small contribution to the overall declines in baseline demand seen in Model 1. Overall, bias associated with failing to control for drought awareness is highest in years 2002 and 2006, years in which the drought index is increasing, which suggests that drought awareness had a significant short-term impact on water demand in these years.

Next, with regards to the question, "*Do some types of news (articles about drought-related policies versus news on the general need for conservation) have more of an impact on demand than others?*" results are more ambiguous due to the "mixed messages" problem and the fact that the different types of news are highly correlated. Without additional data (survey work) to know how consumers interpreted the news they saw during and after the drought, it is difficult to know if restrictions news truly had little impact on consumers or if the small coefficient for "Mrestrictnews" results from some consumers increasing water use in response to restriction-related news from 2002-2005. This problem is exacerbated by the fact that restrictions news has a fairly high correlation with conservation news (a variable that may also cause consumers to increase water use at some times)[2], which may make it difficult for the model to estimate the separate

[2]The Google News search for the "water conservation" search term produced a much less homogenous set of articles than did searches for water rates and restrictions. While the majority of content of "water conservation" articles highlighted the need to conserve, others related to subjects like water conservation efforts to date or utility plans to promote water conservation—subjects that, based on the literature, could either keep the subject of conservation fresh in consumers' minds or convince them that further conservation efforts are not needed, given that the utility has the problem "under control" (Syme, 2000).

impacts of these two types of articles. Nevertheless, it appears that price-related news had a stronger impact throughout the period of study than did restrictions or general conservation-related news, a finding consistent with the literature that states consumers are more likely to respond to messages that tell them how they will directly feel the effects of the drought. Lastly, the fact that the impact of the news variable coefficients grows when the news is disaggregated could also mean that a consumer conserving as a result of awareness of one type of policy (say, restrictions) cannot simultaneously respond to news on the general need for conservation and/or prices.

In answer to the third research question, "*Is there a difference in pre- and post-drought baseline water demand, even after drought awareness and utility policies are controlled for?"*

we can reject the null hypothesis that the coefficients for any of one the post-drought year coefficients is equal to zero. In fact, water demand is significantly decreased from 2003 on (even after utility polices and awareness are controlled for), and the decrease in baseline demand is actually larger as we move further away from the drought, as compared to during the drought itself in 2002. This suggests that there has been a fundamental change in water use in Colorado Springs, and this change is not attributable either to utility policies or to short-term drought awareness. Possible explanations for these large decreases are that the drought experience, combined with price increases and institution of year-round block rate pricing in 2006, induced consumers to make changes in home water-use technology (install new water-efficient appliances) and/or water-use habits. This idea coincides with models results, which show that a large part of decreased demand in “Drought Year 2006” is attributable to awareness and that larger decreases in demand (relative to 2002-2005) occurred in subsequent years.

VI. CONCLUSIONS

Based on these results, one can conclude that drought-related news did have an impact on water demand for this Colorado water utility immediately after the 2002 drought; in fact, results show that water demand would have been 3% higher in the first defined year of the drought if not for drought awareness. It also appears that the short-term reaction to drought-related news may have fluctuated as policies and/or the content of news varied after the height of the drought, though it is impossible to know how consumers interpreted drought-related news at the time. As such, more research is needed regarding how consumers interpret and react to drought-related news and utility demand-management policies. However, despite this ambiguity over the aggregate effects of drought awareness, results here show that the impacts of some types of news may be quite large; in fact, the coefficient for news related to voluntary watering restrictions has a value of -0.04. Lastly, results here show that failing to account for awareness causes the largest amount of bias in estimating baseline water demand in the immediate aftermath of shocks (natural or policy-related); this was the case in drought year 2002, the height of the water shortages, and in 2006, when block-rate pricing and larger price increases became year-round policy for the water utility.

After controlling for drought awareness and utility policies, we still find that water demand has fallen significantly in the post-drought period. In accordance with the energy literature, consumers are likely to make changes in consumption behavior once (among other things) some “threshold” level of aggregate awareness is reached and once they experience the negative impacts of shortages. Though there is no way to definitively prove the former, the latter criteria has clearly been met in the service area studied here, where water news coverage of drought and utility conservation policies (especially price increases) have brought the issue of drought to residents’ attention. This suggests one of three things: either consumers’ water-using behaviors have changed (for instance, consumers now take shorter showers); they have made changes in home water-use technology that have led to permanent declines in demand; or a combination of behavioral and technological change has contributed to observed decreases in demand. In order to answer these questions, researchers need to survey consumers regarding how they have changed behavior in response to drought and drought-related policies which told consumers that the utility’s approach to water provision had changed. Similarly, end-use studies/survey work is needed to find out if the drought experience induced consumers to install new water-efficient appliances once higher prices and block rates made them feel the effects of the drought directly. As such, though this work shows that drought awareness did impact water demand in the immediate aftermath of the drought in this utility service area, further work is needed regarding how the questions of how consumers interpret drought-related news and if/how the short-term effects of drought awareness estimated in this model were solidified into long-term reductions in water demand.

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II. APPENDIX 1: TABULATING FREQUENCY OF DROUGHT-RELATED ARTICLES USING "GOOGLE NEWS"

The "Advanced archive search" tool of "Google News" was used to tally the number of drought-related news articles that appeared during each month from 1996-2010. Specifically, the archive search was performed as follows: six total word/phrase searches were performed, three in each of the major newspapers in question, respectively. For each paper, searches were performed to find articles containing both the words "Drought Colorado" and (in three separate searches) one of the exact phrases, "water conservation," "water restrictions," or "water rates." These search terms were chosen so that news articles could be found that related to the severity of the drought and resulting need for water conservation and for use of utility demand-management policies.

The search feature of "Google News" is depicted below. As seen on the sample results screen, after a search is performed, the archive presents a timeline depicting the frequency of news related to the search terms. It is then possible to click on the timeline to narrow the search down by year and by month. Using this feature, the total number of monthly articles containing the key words and phrases were tabulated; the "crisis aware" variable was then constructed by summing the total number of articles (by month) from both papers that contained the above-mentioned key phrases.

A few notes about construction of the “crisis aware” variable warrant mentioning. First, no attempt was made to read through individual articles for the purpose of content analysis, primarily because “Google News” does not provide full text for all articles. As such, there could be a few articles included in tabulations that do not directly relate to municipal water shortages and demand management programs. Nevertheless, it was felt that analyzing the articles when full text was not always available and deciding whether to include them in tabulations might become a subjective process. For this reason, search results were scanned to ensure that no blatantly non-related articles were included in our counts, but no further analysis of specific articles was made.

http://news.google.com/archivesearch

Google news

Advanced News Archive Search

Advanced archive search tips | About News archive search

Find results	with **all** of the words	Drought Colorado	Submit
	with the **exact phrase**	“Water conservation”	
	with **at least one** of the words		
	without the words		
Date	Return results published between	1996 and 2010 e.g., 1998 or 04/30/2004	
Language	Return results written in		
Source	Return results that come from	____________ e.g., New York Times or NewsBank	
Price	Return articles with the following price		
View	Search articles	Show full timeline	X Show news timeline

Figure 5: Google News Search