USING WATER BILLS TO REINFORCE PRICE SIGNALS: EVIDENCE FROM THE US

S. Gaudin

Department of Economics, Oberlin College, Oberlin, OH 44074, USA,
sylvestre.gaudin@oberlin.edu.

Abstract
In areas subject to drought and/or high population growth, measures to encourage conservation have become an important part of water management and planning. Residential consumer's low sensitivity to prices reduces the effectiveness and desirability of using price signals as a conservation tool. We hypothesize that consumer's sluggish response to prices is partly due to the fact that price information is not conveniently available to them. If the hypothesis is true, including clear price information on water bills should reinforce consumers' sensitivity to price and therefore increase the power of price-based policies in demand management strategies. A standard aggregate water demand model is augmented with qualitative variables describing the informational content of bills and estimated using a cross section of US utilities. Our results indicate that a utility that spells out unit prices on the water bill can achieve the same level of conservation as others with a thirty to forty percent lower rate increase. We find no evidence that non-price information such as history of use or conservation messages has a significant effect on demand.

Keywords: Billing; demand; residential; utilities; water.

INTRODUCTION

Historically, growing cities in the US have relied on expanding supply to satisfy rapidly increasing water demands. However, as new supply sources become more and more difficult to secure, measures to encourage conservation have become an important part of water management and planning, especially in areas subject to drought and/or high population growth. Water conservation can be fostered using non-price based policies such as technological mandates, education campaigns, or rationing; it can also result from changes in rate structures and price increases. The effectiveness and desirability of price instruments, however, depends on the price elasticity of demand, a measure of the magnitude of changes in quantity demanded in response to a given price change. The economic literature on residential water demand abounds in low price elasticity estimates. For example, the average of price elasticity from 18 studies of annual residential water demand reported in Hanemann (1997) is -0.46 (computed from Hanemann, 1997, Table 2.5, pp 67-72). The lower the price elasticity, the greater the price increase needed to absorb a given shortage. In practice, large price increases are unlikely to be implemented because of distributional implications and political pressures. Higher price elasticity would increase the effect of price signals, increasing the attractiveness of price-based policies. The question is whether utilities can influence the magnitude of price responses in their service area. If the weak sensitivity to price stems from the intrinsic nature of water as a necessity to life, as is often implicitly assumed, then nothing can be done short of finding substitutes for water; but little of the water used in urban areas of the US can be considered a necessity (Baumann & Boland, 1997). Basic economic theory points to at least two other reasons why consumers would not be responsive to price in their decision to consume water: water bills constitute a small portion of their budgets, and price information is imperfect. This article is concerned with the latter.

We hypothesize that residents' sluggish response to price is partly due to the fact that the information necessary to make informed decisions is not conveniently available to them. Even though the information can generally be obtained at no cost from the utility or by performing a simple calculation on the bill, individuals do not typically make the effort. If this hypothesis is valid, including clear price information on water bills should increase price elasticity. Today, some water conservation guidelines include the layout and informational content of bills as a tool to foster conservation: notably, the Environmental Protection agency (EPA) recommends that bills be "informative" and "understandable" (see the EPA website at www.epa.gov); state plans have also started to include informative bills in their recommendations (e.g. Envision Utah, 2002). However, econometric studies of residential water demand have ignored variation in billing practices across communities when estimating price elasticities. The experience of gas and electric utilities gives some indication that the content and presentation of bills matter. For example, Fast (1990) found a significantly larger price elasticity of residential electricity demand after the 1985 change to "plain language" bills in the state of New York. Fast's study provided evidence of the overall effect of the new bill but could not identify the specific effect of price information.

Growing cities, especially those in the West and Southwest of the United States but also in water scarce areas around the world, would benefit from understanding whether slight modifications of billing formats could reinforce the effectiveness of price signals, reducing the likelihood of economic shortages —understanding that shortages are reduced if people voluntary reduce consumption when prices increase in response to reductions in supply. We collected representative residential consumer water bills from utilities across the US to document the variation in billing practices and to test the impact of billing information. Seventeen percent of the utilities in our sample clearly indicated marginal prices next to unit consumed on the bill while 79% gave no price information other than total amount due. We used this data along with data from secondary sources to estimate a standard water demand model where features of the bill may affect price elasticity. The analysis indicates that the presence of clear price information on the bill has a statistically significant impact on price elasticity, increasing absolute values of elasticity estimates by a factor of 1.5. Results are not conclusive for other types of information.

WATER DEMAND MODEL AND DATA

Model specification

Base demand model. We use an aggregate water demand model to be estimated using cross-sectional community level data, i.e. all our variables are representative of the community as a whole rather than a specific consumer. The use of aggregate cross-sectional data is motivated by the nature of our quest: since the structural content of utility bills is the same for all residents in a community and changes infrequently over time, this research would not gain from using household-level or pooled cross-sectional data. Our choice of demand variables, functional form, and estimation procedure are guided by insights provided by a large number of published studies, by data availability, and to facilitate the interpretation of coefficients of interest to this study (see Renzetti, 2002 for a review of the literature). We base our analysis on a standard aggregate water demand model where per capita consumption (Qpc) depends on average price (AP), the average level of income (I), average household size (H), population density (D), average annual rainfall (AAP) and number of hot days ($T90$):

$$Qpc=f(AP, I, H, D, AAP, T90) \tag{1}$$

While *AAP* is a 30-year average and as such will capture structural differences between communities mostly related to outdoor water use and practices, *T90* is the number of days when temperature exceeded 90°F (32.2°C) during the survey year and will capture both structural and temporary features of water demand. It is likely that a high level of *T90* will not only increase outdoor water use due to higher evaporation but also possibly increase indoor water use due to more frequent washing and showering.

Although a few studies have shown that, under some circumstances, the Marginal Price specification (MP) may be superior to the Average Price specification (AP) (Nieswiadomy and Molina, 1991; Taylor *et al.*, 2004), many have provided evidence that, in practice, consumers tend to respond to average prices for water and electricity (Foster and Beatie, 1981; Shin, 1985; Griffin and Chang, 1990). We recognize that people may respond differently to marginal prices depending on whether price schedules are increasing, decreasing or uniform (Nieswiadomy and Molina, 1991; Olmstead *et al.*, 2003). Unfortunately, although we have qualitative information on the type of rate structure that utilities used in 1995/6, we do not know the price schedule and cannot identify the amount of fixed and variable charges for each utility. Without knowledge about fixed fees and free allowances, we cannot distinguish between cases when the marginal price is less, equal to, or greater than the average price. In addition, using MP with heterogeneous price structures would create additional estimation and interpretation problems. Since there is no evidence that people respond differently to average prices across rate structures, the AP specification allows us to mix rate structures in the sample. One more argument in favour of the AP formulation is that we are using aggregate data where the unit of observation is the community served by a single utility; Martínez-Espiñeira, (2003) formulates an aggregate model using both AP and MP specifications and finds no improvement with MP. On theoretical grounds, while we recognize the appeal of using marginal prices in demand analyses and the fact that elasticity estimates are affected by the choice of price variable (Espey *et al.*, 1997), the magnitude of the effect of information on price responses (the focus of this study) should not be affected.

Modified demand model. Price and quantity-related billing information variables (X) do not directly affect preferences but are assumed to enter the demand equation through their effect on price elasticity so each variable X_i is interacted with the price variable. Messages (M) aimed at sensitizing consumers to the importance of conservation, however, may affect demand independently of prices through their potential effect on consumer's preferences, which would shift the demand curve. Noting that the choice of functional form does not systematically affect elasticity estimates at the mean (Espey *et al.*, 1997) we choose a log-log form to obtain estimates that are easily comparable with the rest of the literature, straightforward to interpret, and consistent with theory. The following relationship is assumed:

$$\text{Ln}(Qpc) = \alpha_0 + \alpha_1 M + \beta_0 \ln(AP) + \sum_i (\beta_i \ln(AP) X_i) + \gamma_1 \ln(I) + \gamma_2 \ln(D) + \gamma_3(H) + \gamma_4 \ln(AAP) + \gamma_5 T90 \qquad (2)$$

Price elasticity in a standard low information water bill is β_0 while price elasticity on a bill that includes information item i is $\beta_0 + \beta_i$.

Data

Primary source data on water bills. The American Water Works Association (AWWA) periodically collects data on member utilities across the United States. In 1996, 3,200 utilities were surveyed out of a membership base of approximately 4,000, representing over two-thirds of the 500 largest U.S. utilities (there are approximately 56,000 utilities in the U.S. but most of them have a customer base of less than 500). 898 utilities completed the survey, of which 501 served residential customers. After removing utilities with un-metered service or seasonal rat, 495 utilities remained for us to locate and contact by phone during the summer of 2003. The goal was to find out what information was given on a typical residential water bill, particularly the type of information that could potentially affect water use. Since most utilities used December 1995 as the ending date for the yearly data they provided to the AWWA, we asked about the format of the bill as it was in 1995. We obtained usable information on 383 utilities located in 46 states. Although the sample cannot be considered representative of US utilities, sample selection cannot be related in any systematic manner to variables in the demand equation and therefore may be considered random for our analysis.

The kind of information given on water bills from city to city varied along several dimensions. All bills included the quantity used and total amount due for water separate from other charges but there was significant variation on whether the bill included marginal price information and history of use. Table 1

summarizes our survey results on information variables that we found to differ significantly across utilities. Twenty percent of all utilities gave explicit price information on the bill. For history of use, a simple comparison to the same period last year was the most common (23% of utilities overall), while only six percent gave more extensive historical data (multiple months, generally presented with a graph). Although price information and consumption history are positively correlated (ρ= 0.27, p-value=0.00), many utilities with price information do not include history and vice-versa. Among the bills that included price information, 32% also gave simple history and 13% gave more detailed history (compared to 23 and 6% in the full sample); 40% of all bills with consumption history included price information (compared to 20% in the full sample). There is no evidence of correlation between price information and conservation messages on the bill (ρ = -0.03, p-value=0.53). Eight percent of the bills with price information gave conservation messages (compared to 10% for the full sample) while 16% of the bills with messages gave price information. The prevalence of billing information among utilities that reported using increasing block prices and utilities in the West is addressed in the econometric analysis. Finally, some utilities used the same bill to charge other utilities such as sewer, refuse, gas and/or electric. The effect of combined billing on water use could be two-fold. If the customers only look at the bottom line and there is little breakdown, it reduces the consumer's ability to understand the cause of changes in the total bill. On the other hand, since the total bill will be larger, individuals are more likely to pay attention (recalling the fact that price elasticity tends to be higher for goods that constitute a larger portion of income). Other utilities were included in about three fourth of the bills (286 with sewer charges and 59 with energy charges, of which 55 with both sewer and energy). Bills with sewer and/or energy charges were evenly distributed across regions and rate structures.

Table 1. Features of 1995 water bills by region and rate structures.

	Full	Region[a]					Rate structure[b]		
	Sample	MW	NE	SE	SW	W	DB	IB	UR
Number of collected bills:	383	109	64	77	31	102	130	104	149
Percent with:									
Price per unit consumed[c]	17.2	11.0	23.4	3.9	19.4	29.4	8.5	26.9	18.1
Price schedule[d]	2.9	2.8	3.1	5.2	0	1.2	2.3	2.9	3.4
Consumption history I[e]	22.7	11.0	7.8	15.6	28.6	50.0	10.8	39.4	21.5
Consumption history II[f]	5.7	1.8	0	3.9	16.1	11.7	2.3	14.4	2.7
Conservation messages	9.7	4.6	3.1	6.5	6.5	22.6	3.0	18.3	9.4
Other non-price info[g]	10.2	3.7	7.8	6.5	9.7	21.6	3.9	17.3	10.7

[a] According to the US Census.
[b] DB=declining block rate; IB=increasing block rate; UR=uniform rate.
[c] Rate per unit indicated next to units consumed.
[d] Bills that include information about the rate schedule on the bill but not next to consumption.
[e] Consumption in the same period in the previous year is included for comparison with current period.
[f] Consumption for all periods in the previous year is included (subset of bills with Consumption history I).
[g] Includes features used by a small number of utilities that provide information on quantity including: benchmark comparisons, daily consumption, and percentage changes in consumption.

The following qualitative variables are created to capture billing heterogeneity; the first six are assumed to affect water demand through quantity responses to price; the last one may affect preferences directly:
- *priceinfo*: price information appears anywhere on the bill (20.1% of bills).
- *history*: comparisons with past quantity consumed is provided (28.4% of bills).
- *otherinfo:* there is other relevant quantity-related information on bill (10.2% of bills).
- *sewer*: sewer charges are included (74.6% of bills – some also include power).
- *power*: electricity and/or gas charges are included (15.4% of bills – most also include sewer).
- *IB:* the utility reported using an increasing block rate structure (27.2% of bills).

- *Message*: the utility included conservation-related messages on the bill (9.7% of bills).

Secondary data sources. All variables pertaining to price and quantities and other characteristics of the utilities come from the 1996 AWWA survey. Per capita quantity was calculated as the ratio of volume of residential sales to retail population served and average price as the ratio of total revenue to total volume of residential water sales. Density was calculated as size of the service area divided by the retail population served. Census data (2000) on average income, median income and household size was aggregated to match complex service areas. The 1990 Census did not allow us to match a good number of service areas because of changes in zip codes or names of places. Finally, the Annual Climatological Summary of the National Oceanic and Atmospheric Administration (NOAA) was used to locate the closest weather station with 1995 data. Table 2 presents summary statistics and description of the quantitative variables used in the estimation.

Table 2. Summary statistics.

	Description	Mean	Std. Dev.	Min	Max	N[a]
Qpc	Per capita residential consumption in thousand gal./yr (1000 gal=3.79 m³)	32.48	15.94	7.47	112.6	378
AP	Average price of water in US$ per thousand gal. (1000 gal=3.79 m³)	2.33	1.04	0.13	6.30	380
I	Per capita income in thousand US$	22,201	8,584	9,480	98,643	383
H	Avg. number of household members in housing units	2.56	0.37	1.71	4.91	383
D	Population density in persons per square mile (1 sq. mile = 2.59 km²)	2,246	2,033	8.07	11,923	353
AAP	30-year average annual precipitation in inches (1 inch=25.4 mm)	35.08	13.28	1.66	79.49	383
T90	Number of days with temperature > 90°F (32.2°C)	41.00	33.40	0	172	383

[a] Missing entries in the AWWA database reduce the sample size for *Qpc*, *AP*, and *D*.

ESTIMATION, RESULTS AND DISCUSSION

Estimation issues

The model is estimated using Ordinary Least Square (OLS) after testing for the presence of endogeneity. The presence of endogeneity would result in correlation between an explanatory variable (notably, the average price) and the error component of the dependent variable, thereby violating a basic assumption of OLS and creating bias in coefficient estimates. The existing literature on residential water demand recognizes different reasons for believing that the price variable in a residential water demand model may be endogenous. One potential source of endogeneity comes from the use of average price in a sample where some utilities have non-linear price structures. The use of aggregate community level data mitigates the problem generated by the simultaneous determination of price and quantity in consumer choices (Shin, 1985), thus reducing the likelihood of a simultaneity bias. The endogeneity in this model is more likely to come from the fact that marginal price is usually not equal to average price and/or from the fact that price and price information may be correlated with unobserved community characteristics that also determine water usage (Nauges and Thomas, 2000). In the first case, measurement errors may result in biased OLS estimates if, for some utilities, marginal price would be a better specification. Following Hausman (1978), we can test for this type of endogeneity with appropriate instruments by comparing OLS and Two Stage Least Squares (2SLS) results, assuming that in the absence of endogeneity, 2SLS estimates are consistent but inefficient. We perform the test using the standard

demand model (excluding information dummies). In the two-stage procedure, the log values of the total charges for 3750-gallon and 7500-gallon monthly bills (14 and 28.4 m^3) are used in addition to the other exogenous variables to instrument price. To gauge the appropriateness of the instruments, we use them to obtain predicted values for the average price variable. Correlation between the predicted and the original average price variable is 0.65. A linear regression of the predicted value of *AP* on all the predetermined endogenous variables of the demand equation produces residuals that do not significantly explain the variation in Qpc (p-value of 0.57). We cannot reject equality between OLS and 2SLS estimates) with a χ^2 value of 3.46 (p-value=0.75), indicating no systematic bias in the OLS estimates.

In the case of price information, the endogeneity problem would arise if the quantity of water use per capita motivates utility managers to include more information on their bills (e.g. if they believe it can foster conservation). We do not have good instruments for the information variables to test formally for this source of bias but several observations indicate that the problem is not likely to significantly affect our results. First, utilities do not change bills frequently --most utilities included in our survey were still using the same bill in 2003 as in 1995 and when the bill was changed since 1995, the previous one had been in effect for as long as the employee could remember. Second, even if aggregate water use may affect the likelihood of utilities choosing to include information, our sample will include many utilities that did not yet react to the quantity signal. Since the format of water bills cannot be changed easily in response to changes in current quantity demanded, it is more likely to be correlated with included structural variables (such as average annual precipitation), or to utility characteristics (such as utility size), than to the dependent variable. Finally, while respondents to our survey indicated that qualitative messages on bills were used to influence quantity used, none indicated that they opted for including detailed price information for conservation purposes; we note that 1995 water bills formats could not have been influenced by the US EPA guidelines that were drafted post 1996 following a mandate from the Safe Drinking Water Act Amendments.

Results and discussion

The base model (excluding billing information) is estimated as a benchmark for comparison with the literature. In order to address concerns about the higher prevalence of billing information in the West and Southwest and among utilities that reported using increasing block prices, the modified model is estimated for the full sample and for sub-samples that exclude utilities in the West and Southwest as well as utilities using IB pricing. Results are detailed in Table 3. The base model gives coefficients comparable to previous results in the literature with a price elasticity of -0.37 and income elasticity of 0.30. The coefficients on average rainfall and high temperatures are of expected sign and significant. Density, our proxy for describing the housing stock and size of yards, has the expected negative effect on per capita water use. The significant and positive effect of household size on per capita consumption is likely due to our using aggregate data: household consumption is clearly positively related to household size and in our sample, per capita and per household usage is highly correlated ($\rho = 0.93$).

Including the qualitative information variables preserves the magnitude and significance of coefficients on all variables in the basic model except for the price elasticity, which is significantly affected by the presence of price information on the bill in all estimations. Using the full sample, we obtain a price elasticity that increases from -0.35 to -0.51. Assuming constant elasticity, this means that for any given quantity reduction target, the required price increase can be 30% lower with price information on the bill; for example, a 10% decrease in quantity requires a price increase of approximately 20% when price information is on the bill, compared to 29% otherwise. We cannot reject the hypothesis that all other types of information have no effect on the price elasticity with p-values of 0.5 for *M* (Messages) and 0.7 or greater for non-price information variables interacted with the log of average price. All linear combinations of coefficients of non-price information variables were also insignificant. Finally, there is no evidence in the sample that increasing block structures cause higher elasticity independently of price information. The evidence on the impact of larger bills (through the inclusion of sewer and/or power on the same bill), is also inconclusive. We note that in our data, billing frequency did not have a significant

effect on demand either. Insignificant results on billing information other than price are not reported in Table 3 but were left in the regression to ensure that the coefficient on price information was not capturing the effect of other correlated features of the bills or the utility.

Table 3. OLS estimations results.

Dependant variable ln(Qpc)	Base model n=349	Model with qualitative variables from the water bill[a]			
		Full sample n=349	Less West n=254	Less WSW n=226	Less IB n=252
ln(AP)	-0.37***	-0.35***	-0.28***	-0.28***	-0.35***
(Standard errors)	(0.039)	(0.053)	(0.063)	(0.069)	(0.064)
ln(I)	0.30***	0.31***	0.31***	0.25***	0.30***
	(0.057)	(0.058)	(0.074)	(0.083)	(0.071)
HHsize	0.25***	0.27***	0.24***	0.34***	0.33***
	(0.048)	(0.050)	(0.092)	(0.11)	(0.059)
ln(D)	-0.048***	-0.041***	-0.023	-0.16	-0.037**
	(0.016)	(0.016)	(0.020)	(0.23)	(0.019)
ln (AAP)	-0.23***	-0.23***	-0.23***	-0.14	-0.20***
	(0.035)	(0.036)	(0.063)	(0.10)	(0.044)
dt90	0.0015***	0.0015***	0.0023***	0.0018*	0.0024***
	(0.0005)	(0.0005)	(0.0007)	(0.0010)	(0.0007)
ln(AP) × priceinfo		-0.16***	-0.20***	-0.21***	-0.14**
		(0.051)	(0.060)	(0.065)	(0.065)
Intercept	1.07*	0.88	0.72	0.72	0.70
	(0.59)	(0.61)	(0.74)	(0.83)	(0.74)
Adjusted R-squared	0.441	0.450	0.310	0.253	0.425
F-test	46.84	22.84	9.76	6.85	16.44

[a] Insignificant results are not reported here. Variables included in the regressions but insignificant (individually or in linear combinations) are the interaction of AP with *History, otherinfo, sewer, power,* and *IB* as well as the Message dummy. Excluding these variables from the regressions did not change results on significant variables
*significant at the 10% level;
**significant at the 5% level;
*** significant at the 1% level or better.

The magnitude and significance of our results appear robust to sample selection and not solely driven by specific features of utilities in the West and Southwest, where attitudes toward water are likely to be different than in the rest of the country, and of those with increasing block price structures. The regression without western states reveals a larger increase in elasticity with price information (although the coefficients are not statistically different from each other). While total price elasticity is approximately the same (-0.48), elasticity for utilities without price information is reduced to –0.28. Such numbers imply that the percent price increase required to obtain any size reduction in quantity demanded is 40% less than required without the price information. Excluding the Southwest in addition to the West reduces the magnitudes and significance levels of some of the coefficients, but results on price elasticity and information variables are virtually unchanged. Finally, excluding utilities across the US that reported using increasing block rates slightly reduces the estimated effect of price information on price elasticity but not significantly so.

CONCLUSION

We asked the question whether the demand for residential water could be made more elastic by

providing consumers with more informative water bills. We documented differences in water billing information after collecting the information from utilities that responded to the AWWA's 1996 survey and used the data to run a simple residential water demand model where billing information can affect price elasticity. We found that price information on bills increases responsiveness to price, indicating that individuals may not take the time to enquire about marginal prices or perform mental calculations from their bill, but do react more strongly when prices are transparent. The magnitude and statistical significance of the effect is large enough to merit notice: *ceteris paribus*, a utility that gives marginal price information on the water bill can attain the same level of conservation with a 30% lower price increase. The inclusion of other types of information is not found to significantly affect water demand.

Although additional data collection will be necessary to elicit the role of billing information for different price structures and to test whether including price information can reinforce the response to marginal prices as opposed to average prices, our results give a strong indication that billing information should not be ignored in studies of residential water demand and as a demand management tool. We hope the results of this research will encourage water utilities in the United States and other countries to use bills to their full potential by incorporating information that is most likely to make a difference for their community at the least cost.

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