SECTION X

EVALUATION OF ARTESIAN'S RESIDENTIAL DSM MEASURES: WATER DEMAND ANALYSIS THROUGH A PANEL STUDY

To quantitatively evaluate Artesian's water DSM impacts, a regression model with proportional changes (between the two years) was adopted (instead of a cross-sectional model for a single year). The negative value of PRICE coefficient in the cross-sectional model, whether it is linear or logarithmic, only indicates that those customers who faced a higher average price of water (usually small water consumers) were more likely to have lower water consumption compared to large water consumers who faced a lower average price. Fundamentally, a cross-sectional model has a limitation in terms of supplying information on changes in price and consumption which are essential for the estimation of price elasticity.

The coefficient is also likely to be biased upward because the average price paid by customers depends upon the quantity consumed. To avoid the problem inherent in the cross-sectional model, a linear regression model which contained the variables representing proportional changes in consumption and prices was constructed.

For this regression model, the independent variables were conceptually based on the variables statistically significant in the previous preliminary t-tests (in Table 9) and correlation analyses (in Tables 12 and 13). The dependent variable was the growth rate of water consumption between 1992 and 1993, between 1992 and 1994, between 1992 and 1995, between 1992 and 1996, and between 1992 and 1997. The independent variables included in the equation were PRICE from the simple correlation analysis and INFORM and DEVICES from the t-tests.[2] These three variables are the policy variables on which this project focuses.[3]

For consistency with the previous model constructed for the period 1992-93, the same variable specification was adopted in the 1992-94, 1992-95, 1992-96 and 1992-97 equations. The dependent variable of WATER and the independent variable of PRICE were entered in the equation in proportional change forms between the two years {expressed as WATER(R) and PRICE(R), respectively}, while INFORM and DEVICES were inserted as base-year variables. The general form of the equation was as follows:

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[2] The variables selected here are those independent variables which have statistical significances with all of the three water consumption growth rates.

[3] In the evaluation of water conservation devices provided by Artesian, both KITS and DEVICES were considered, but the impact of DEVICES was only reported because KITS refers to the program in place prior to CCP. CCP was initiated by the State Department of Natural Resources and Environmental Control in 1992.

$$\text{WATER (R)} = \alpha_0 + \alpha_1 \text{ PRICE (R)} + \alpha_2 \text{ INFORM} + \alpha_3 \text{ DEVICES} + e$$

Where,

WATER(R):	Proportional changes in day- and weather-adjusted water consumption during the summer months between the two periods $\{(Q_1 - Q_0) / Q_0\}$
PRICE(R):	Proportional changes in average prices of water during the summer months between the two periods $\{(P_1 - P_0) / P_0\}$
INFORM:	Household water conservation information from Artesian's bill inserts and pamphlets
DEVICES:	Use of water conservation devices provided by Artesian
e:	Error terms

In our regression model with proportional changes (i.e., WATER(R) and PRICE(R)), the intercept term (a_0) can be suppressed or estimated in the equation. Generally speaking, unless there is strong a priori expectation that the intercept term is in fact zero, it is advised to adopt the conventional intercept-present model (Gujarati, 1988).[4] One method to decide whether a_0 should be included or excluded is to empirically estimate the equation with and without a_0. If a_0 is not statistically significantly different from zero, then the suppressing intercept term is justified.[5]

Under the assumption that the coefficient of water price (PRICE(R)), a_1, is statistically significant, its absolute value can be interpreted as follows:

$\alpha_1 > 1$	Conservation rate greater than price change (elastic)
$\alpha_1 = 1$	Conservation rate proportional to price change (unit elasticity)
$\alpha_1 < 1$	Conservation rate lower than price change (inelastic)
$\alpha_1 = 0$	Conservation rate not affected by price change (perfectly inelastic)

When the coefficients of INFORM and DEVICES, α_2 and α_3, are statistically significant, then they can be interpreted as follows:

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[4] If in fact there is an intercept in the model but we fit a regression through the origin, it will violate an assumption of the linear regression model, leading to a specification error.

[5] This points out that if the intercept term is in fact absent, the slope coefficient may be estimated with far greater precision than when an intercept term is left in (Gujarati, 1988: 138).

$\alpha_2 < 0$ — Residential customers with higher levels of water conservation information tended to conserve more water than those who had lower levels of conservation information

$\alpha_3 < 0$ — Residential customers who used water conservation devices provided by Artesian were likely to conserve more water than those who did not

The results of the above equation are presented in Table 80. The intercept term was not suppressed in the equation because it was statistically significant. Four equations, for the periods of 1992-94, 1992-95, 1992-96 and 1992-97, were contrasted in reference to the 1992-93 equation. In all four equations, the F-values were far greater than the critical F-value of 2.965, indicating that these equations were statistically significant. The R^2s of all four equations were modest, greater than 0.2. All the signs of the estimated coefficients conformed with prior expectations. No significant problems existed with heteroscedasticity and multicollinearity. The most statistically significant policy variable was PRICE(R), followed by DEVICES and then INFORM. INFORM was significant at the 0.05 level only in the 1992-95 equation, whereas DEVICES was significant in the 1992-93, 1992-94 and 1992-97 equations.

Table 80
Results of Regression Models for Water Demand
Based on Nominal Prices (1992-97)

Equation	Variable				Statistics		
	PRICE (R)	**INFORM**	**DEVICES**	**Constant**	**R^2**	**F Value**	**Cases**
1992-93	-0.49601**	-0.02844	-0.20400**	0.21611**	0.173	35.216	510
	(-9.546)	(-0.795)	(-3.379)	(7.940)			
1992-94	-0.66090**	-0.05054	-0.14693**	0.24583**	0.311	76.271	510
	(-14.243)	(-1.661)	(-3.200)	(10.530)			
1992-95	-0.58612**	-0.08723*	-0.09605	0.23074**	0.208	44.315	510
	(-10.445)	(-2.216)	(-1.667)	(7.343)			
1992-96	-0.53065**	-0.06906	-0.10676	0.21055**	0.214	45.876	510
	(-11.011)	(-1.824)	(-1.909)	(6.785)			
1992-97	-0.45107**	-0.04835	-0.15999*	0.24943**	0.206	43.777	510
	(-11.016)	(-1.117)	(-2.487)	(7.264)			

Note: The figures in the parentheses are t-statistics.
* denotes a statistical significance at the level of 0.05.

** denotes a statistical significance at the level of 0.01.

Since our panel study has a 6-year duration from 1992 to 1997, it is considered to be necessary to adjust for inflation in water prices. Consumer price indexes of 1992-1997 in the Philadelphia-Wilmington-Trenton CMSA were obtained from two sources: *Statistical Abstract of the United States 1997* and *Economic Indicators* prepared for the Joint Economic Committee by the Council of Economic Advisors (May 1998). From the indexes, water prices in 1993 through 1997 were adjusted, and the regression equation was reestimated using the adjusted real prices. The results show that the price elasticities become higher, whereas the coefficients of the constant term become lower in the reestimated equations. As expected, there are no changes in the coefficients of INFORM and DEVICES and such statistics as R^2s and F-values as shown in Table 81. Even though the magnitude of the price elasticities estimated from real water prices was increased in every equation, but the historical trend of price elasticities during 1992 to 1997 was almost identical with those elasticities estimated with nominal water prices.

Table 81
Results of Regression Models for Water Demand
Based on Real Prices (1992-97)

Equation	Variable				Statistics		
	PRICE (R)	INFORM	DEVICES	Constant	R^2	F Value	Cases
1992-93	-0.50821**	-0.02844	-0.20400**	0.20391**	0.173	35.216	510
	(-9.546)	(-0.795)	(-3.379)	(7.613)			
1992-94	-0.69716**	-0.05054	-0.14693**	0.20957**	0.311	76.271	510
	(-14.243)	(-1.661)	(-3.200)	(9.293)			
1992-95	-0.63295**	-0.08723*	-0.09605	0.18390**	0.208	44.315	510
	(-10.445)	(-2.216)	(-1.667)	(6.213)			
1992-96	-0.58896**	-0.06906	-0.10676	0.15225**	0.214	45.876	510
	(-11.011)	(-1.824)	(-1.909)	(5.289)			
1992-97	-0.53255**	-0.04835	-0.15999*	0.16795**	0.206	43.777	510
	(-11.016)	(-1.117)	(-2.487)	(5.268)			

Note: The figures in the parentheses are t-statistics.
* denotes a statistical significance at the level of 0.05.
** denotes a statistical significance at the level of 0.01.

WATER(R) and PRICE(R) were constructed in such a way that the estimated coefficient of PRICE(R) is equivalent to the price elasticity of water demand. An estimated price elasticity of -0.5 in the 1992-97 equation, for instance, means that consumers reduce their demand by 5% when price increases by 10%. This is considered a relatively low elasticity effect, but these magnitudes are still higher than commonly assumed in the case of water. It is important to recognize that these estimates were based on water consumption and prices during the summer months. Thus, the estimated elasticity in this case should be higher compared to the results from models that estimate year-round elasticity effects. The estimated price elasticities are well within the range of reported elasticities of other studies shown in Table 82.

Table 82
Estimated Price Elasticities for Residential Water Demand: Studies Conducted Between 1985 and 1998

Investigator	Year Published	Type of Analysis	Price Elasticity
Wang, Song, Byrne and Yun	1998	510 households, Delaware Panel study, 1992—1997 (Summer)	-0.508 to -0.697
Dandy, Nguyen and Davies	1997	320 households, Australia Panel study, 1979—1992 (Summer)	-0.36 to -0.86
Hansen	1996	Copenhagen, annual per capita Time series, 1981—1990	-0.1
Hewitt and Hanemann	1995	121 households, Texas Panel study, 1981—1985 (Summer)	-1.57 to -1.63
Stevens, Miller and Willis	1992	85 Massachusetts Communities cross-sectional	-0.10 to -0.69
Woo	1992	Hong Kong, monthly per capita time series, 1973—1984	-0.384
Nieswiadomy	1992	430 water utilities, AWWA data cross-sectional	-0.29 to -0.45
Rizaiza	1991	563 customers, Saudi Arabia cross-sectional	-0.40 to -0.780
Nieswiadomy and Molina	1991	101 customers, summer, Texas 1976—80, DBR period* 1981—85, IBR period*	 -0.11 to -0.94 0.78 to -0.295
Weber	1989	12 zones, East Bay Municipal Utility District, California time series and cross-sectional	-0.10 to -0.25
Metzner	1989	City of San Francisco 1974-86, time series	-0.25
Billings and Day	1989	3 water utilities, Arizona time series and cross-sectional	-0.720
Palencia	1988	Metropolitan Manila time-series, 1970—1981	-0.287
Martin and Thomas	1986	Five arid cities (U.S., Kuwait and Australia), cross-sectional	-0.500
Narayanan, Larson and Hughs	1985	33 Utah communities 1976-77, cross-sectional	-0.07 to -0.09

Note: * DBR denotes declining block rates and IBR denotes inclining block rates.

Artesian's delivery of water conservation devices was also found to contribute to water conservation. The estimated coefficients of DEVICES were negative and statistically significant in the 1992-93 equation, in the 1992-94 equation and in the 1992-97 equation.[6] Throughout the panel study period, these results consistently indicate that those customers who received conservation devices provided by Artesian as part of the customer conservation program (CCP) experienced a significantly lower growth rate in water consumption than those who did not participate in the program. More specifically, those who received the devices reduced their consumption by approximately 10 to 20 percent compared to those who did not (as shown in the estimated coefficients of DEVICES). This magnitude of savings is well in accord with other research results, such as the San Jose residential retrofit kit program which achieved a 10 to 11 percent reduction in *indoor* water use (Vickers, 1991).

Artesian's information campaigns through bill inserts and pamphlets have made a modest contribution to the overall water conservation effort, according to our analysis. Even though INFORM was not statistically significant except for the 1992-95 equation, its estimated coefficients for all equations had negative signs, indicating that those customers who received and remembered water conservation-related information supplied by Artesian showed a tendency to consume less water than those who did not. The magnitude of reduction during the summer months between 1992 and 1997 was approximately 5 percent. Few studies are available which deal with the impact of INFORM on water conservation.[7] The southern Arizona experience shows that publicity about water problems appears to have a small impact on water conservation, with an average elasticity of -0.05, and that the effect of publicity remains only as long as the publicity continues (Billings and Day, 1989).

For the equations from the period of 1994, it was possible to elaborate the model by including additional information which was gathered in the survey conducted during November, 1994. The 1994 survey was intended to obtain information on changes in factors affecting water consumption since the last survey conducted during March 1993 (see Appendix B for the 1994 survey instrument). Through the survey, changes in household income (INCOME(R)) and household size (HHSIZE(R)) were identified. HHSIZE(R) turned out to be statistically significant in our preliminary analysis and, therefore, was added in the final equation. The results of the revised equation are shown in Table 83.

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[6] DEVICES in the 1992-95 equation was marginally significant at the 0.05 significance level. The t-value was -1.750, a little lower than the critical t-value of -1.965.

[7] Many studies that have analyzed this factor are based on aggregate data and regions significantly different from New Castle County, Delaware.

Table 83
Results of Revised Models for Water Demand
Based on Nominal Prices (1994-97)

Equation	Variable					Statistics		
	PRICE (R)	INFORM	DEVICES	HSIZE(R)	Constant	R^2	F Value	Case
1992-94	-0.64748**	-0.04662	-0.14049**	0.11391**	0.23753**	0.327	61.081	509
	(-14.030)	(-1.545)	(-3.084)	(3.366)	(10.211)			
1992-95	-0.54984**	-0.08487*	-0.08464	0.17266**	0.21221**	0.232	38.059	509
	(-9.799)	(-2.183)	(-1.487)	(3.971)	(6.769)			
1992-96	-0.50801**	-0.06533	-0.09778	0.13397**	0.19636**	0.229	37.443	509
	(-10.510)	(-1.737)	(-1.760)	(3.164)	(6.312)			
1992-97	-0.43814**	-0.04187	-0.14854**	0.16470**	0.23620**	0.224	36.387	509
	(-10.758)	(-0.975)	(-2.327)	(3.410)	(6.901)			

Note: The figures in the parentheses are t-statistics.
* denotes a statistical significance at the level of 0.01.
** denotes a statistical significance at the level of 0.05.

These revised equations of 1992-94, 1992-95, 1992-96 and 1992-97 explained more than 22 percent of the variance in water consumption growth, a little higher than the previous equations in terms of explanation power. Overall, these equations were also statistically significant as shown in the F-values. All the signs of estimated coefficients conformed with prior expectations. The magnitudes of the coefficients of the three policy variables (PRICE(R), DEVICES and INFORM) in these revised equations were smaller, but not significantly different from the previous equations, implying that the results of our model are stable.[8]

The adjusted real water prices were also inserted in the above revised equations, and the reestimated results are shown in Table 84. As in the cases of previous results shown in Tables 80 and 81, the price elasticities in these reestimated equations are getting larger and the constant terms' coefficients become smaller. There are no changes in the both coefficients and t-statistics of INFORM, DEVICES and HSIZE(R). Also, R^2s and F-values are the same, and the historical trend of price elasticities during 1994 to 1997 has no differences with the trend estimated with nominal water prices.

[8] In these revised equations, the price elasticity and the coefficient of DEVICES were slightly lower compared to the previous equations, whereas the coefficient of INFORM was slightly higher.

Table 84
Results of Revised Models for Water Demand
Based on Real Prices (1994-97)

Equation	Variable					Statistics		
	PRICE (R)	INFORM	DEVICES	HSIZE(R)	Constant	R^2	F Value	Case
1992-94	-0.68299**	-0.04662	-0.14049**	0.11391**	0.20201**	0.327	61.081	509
	(-14.030)	(-1.545)	(-3.084)	(3.366)	(8.995)			
1992-95	-0.59378**	-0.08487*	-0.08464	0.17266**	0.16827**	0.232	38.059	509
	(-9.799)	(-2.183)	(-1.487)	(3.971)	(5.711)			
1992-96	-0.56383**	-0.06533	-0.09778	0.13397**	0.14054**	0.229	37.443	509
	(-10.510)	(-1.737)	(-1.760)	(3.164)	(4.881)			
1992-97	-0.51729**	-0.04187	-0.14854**	0.16470**	0.15705**	0.224	36.387	509
	(-10.758)	(-0.975)	(-2.327)	(3.410)	(4.949)			

Note: The figures in the parentheses are t-statistics.
* denotes a statistical significance at the level of 0.01.
** denotes a statistical significance at the level of 0.05.

The results of our regression analysis for this report indicate that water conservation impacts persist since the price reform implemented in 1992 and also water-saving device promotions and information campaigns by Artesian since 1992. It is interesting to note, however, that the magnitudes of the price elasticities, as shown in Tables 81 and 84, have weakened since 1994, and the inflation-adjusted price elasticities tend to be higher than those estimated with the nominal prices.