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Elasticity of Price Demand for Water for Residential and Commercial Sectors in Nevada

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This publication reports the findings of several studies conducted in Nevada, that estimate the elasticity of demand for municipal water. We discuss why water utilities rely on representative elasticity measurements and why these measurements can vary.

A partnership of Nevada counties; University of Nevada, Reno; and U.S. Department of Agriculture

Introduction[1]

Water utilities and management authorities use **price elasticity of demand for water** to predict the effects of rate changes on water demand. Price elasticity of water demand provides information about how changes to the price of water motivate an increase or decrease in water consumption and how these changes in demand can impact water utility revenues. Accuracy in predicting revenues is necessary to finance, operate and maintain water storage, treatment and delivery infrastructure.

This special publication is intended for utility commissions, water utilities, municipal governments and other individuals interested in understanding water demand and consumer responses to changes in water pricing. This work focuses on factors that cause elasticity measurements to vary and the implications of inadvertently applying an elasticity from one context to another.

Price elasticity of demand is defined as a measure of the percentage change in the quantity demanded resulting from a 1 percent change in the price of a good. Elasticity is a measure of consumers' abilities to respond to price changes and is generally not constant over all levels of consumption (i.e., parts of a demand curve). At low levels of consumption for many goods, consumers facing a price increase may have few alternatives other than to consume the same amount of the necessary good and consume less of other goods. However, at higher levels of consumption of the same goods, water included, a portion tends to be for uses over which a consumer has greater discretion – outdoor water use, for example – and a price increase can more easily be met with a reduction in the amount of water purchased.

"An important benchmark in price elasticity estimates is the value -1.0. Elasticity estimates are **elastic** when less than -1.0 (greater than 1.0 in absolute value)**. Elastic demand** means that a 1 percent increase in price causes a more than 1 percent decrease in quantity demanded. When demand for a good is elastic, an increase in price will cause the firm supplying that good to lose revenue. Elasticity estimates are **inelastic** when between zero and -1.0. **Inelastic demand** means that a one percent increase in price causes a less than 1 percent decrease in quantity demanded. When demand is inelastic a price increase leads to an increase in revenue" (Las Vegas Valley Water District (LVVWD), 2016).

Elasticity of demand is calculated from the coefficients of estimated demand models where quantity demanded is predicted as a function of prices and income, conditional on other factors. We use a large set of data from municipal water utilities in northern and southern Nevada that exhibits substantial variation in seasonality, weather, landscape features, size of household and type of commercial sector, to demonstrate how elasticities are influenced by these characteristics. In particular, this special publication summarizes elasticity estimates from previous studies that are based on five

[1] This Extension publication summarizes the results of recent studies (Rollins, Lott, and Tchigriaeva, 2014; Lott et al., 2014; and Las Vegas Valley Water District, 2016) to estimate price elasticity of water demand for residential and commercial water customers in the Las Vegas Valley Water District, Southern Nevada Water Authority and Truckee Meadows Water Authority.

to 10 years of monthly client billing data, along with additional information from various sources including National Oceanic and Atmospheric Administration (NOAA) for daily weather, property and building characteristics from county tax assessors, and business and employment features from the Nevada Department of Employment, Training and Rehabilitation. While many studies use aggregated data to calculate elasticities over all of the client base, the studies we summarize here estimate multiple demand models for portions of the data in order to generate elasticities for individual components, such as single- and multi-family residential clients, commercial clients and by season. Details regarding these data are found in Rollins, Lott, and Tchigriaeva, (2014); Lott, Tchigriaeva, Rollins, and Stoddard (2014); and LVVWD (2016).

Price elasticity estimates for water across the United States generally are observed as inelastic. An analysis of 64 residential water studies shows an average price elasticity of -0.41 (Dalhuisen et al., 2003). Additionally, elasticity estimates for single-family residences range between zero and -0.5 in the short run and zero to 1.0 in the long run (Worthington and Hoffman, 2008). We discuss in this publication why such ranges in price elasticity of demand for water exist using, as examples, estimates from disaggregated data from southern and northern Nevada.

Price elasticity can be visualized by using a demand curve. Figure 1 illustrates how an identical price change can be associated with two very different changes in the quantity of water demanded. The difference between prices P_1 - P_2 is the same as the difference between prices P_3 - P_4. However, these prices correspond with very different initial levels of consumption and changes in the quantity of water demanded. That is, the difference between quantities demanded Q_3 - Q_4 is much greater than the difference between Q_1 - Q_2. Water consumption at lower levels, indicated by Q_2, often tends to be for uses over which consumers have little discretion, such as for drinking, cooking and bathing. On the other hand, water consumption at a higher level, Q_4, is more likely to be used for purposes over which consumers have greater discretion, such as landscape irrigation, which can be reduced as a response to a price increase and thus warrants a more elastic response. Consumers simply have fewer ways that they can reduce water use when they already are at a lower level of consumption.

A relatively elastic response represents consumers who have greater discretion over their water use, perhaps by using water for nonessential outdoor purposes. In contrast, an inelastic response may be characteristic of consumers who have already responded to conservation messages or use water primarily for essential indoor purposes.

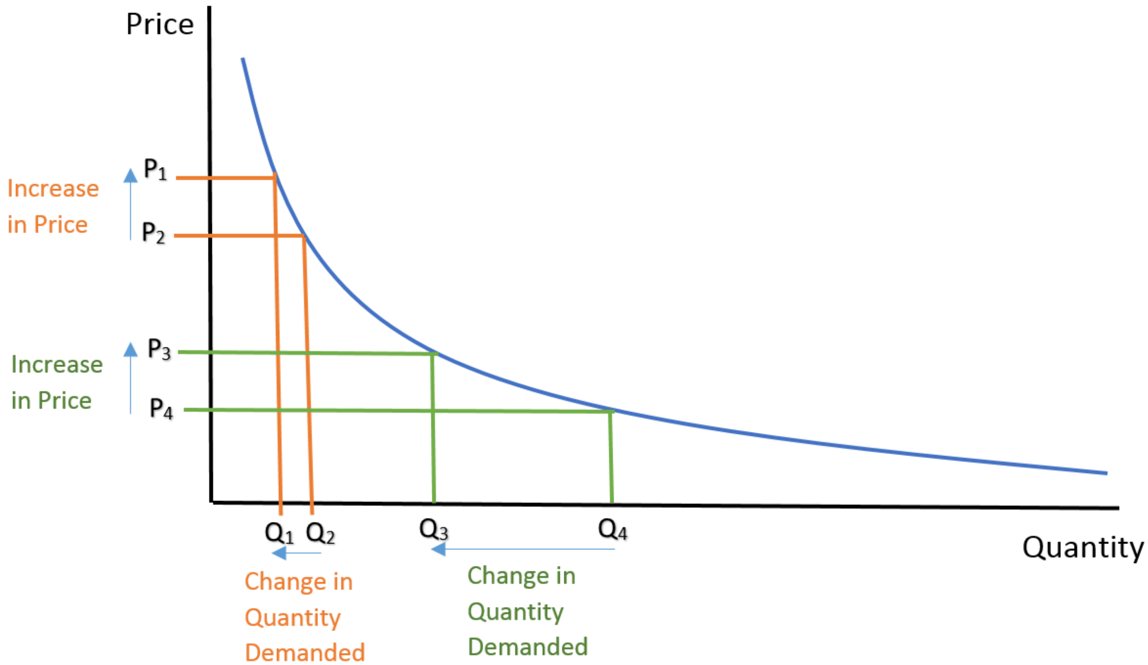

Figure 1. Shows the relationship between price and quantity of water demanded at different levels of consumption.

Water Pricing and Regulation

Water utilities are characterized by large capital expenditures and the inability or inefficiency of having multiple competitors. The term “natural monopoly” is used to describe this situation. As water is a basic need, most communities choose to either own the utility outright or to create a quasi-municipal organization, such as the Las Vegas Valley Water District (LVVWD) and Truckee Meadows Water Authority (TMWA), which answer directly to elected officials.

Utilities require revenue to meet current operating costs, maintain current capital stock, protect water quality, expand the system as the community grows, and secure adequate supplies for the future.

Because competitive market prices do not exist, rates are set and adjusted through a public hearing process. For a public utility, requesting a rate increase is a major undertaking. It usually requires credible growth forecasts, demand analysis and the application of a financial model. Public Utility Commissions are charged with judging the need for rate adjustments through their own analysis.

Analyses, models and scenarios of rate changes are meaningless if they cannot predict precisely how people will respond to proposed rate changes. The estimate of price elasticity is a critical input required to make financial models and scenarios useful to evaluate the effect of a proposed rate change.
It is often not feasible to estimate elasticity of water demand given time, data needs and budget constraints. Therefore, utilities, public utility commissions and other analysts

often use elasticity estimates from published studies. These, however, may not be representative of their own customers due to differences in characteristics that determine specific elasticities. This special publication explores why and how variations in elasticity estimates occur, thereby assisting more-informed decision-making about which estimates to use and why.

Water Conservation and Elasticity

"Demand hardening is the reduction in the ability of a customer (or customers collectively) to achieve further water reductions after relatively easy and inexpensive water reductions have been implemented" (Tabors Caramanis and Associates (TCA), 1994 as cited in Howe and Goemans, 2007). With demand hardening, demand for water becomes even more inelastic. This induced tendency toward increasingly inelastic demand for water during drought can result in a severe impact on utilities' revenues after the drought has passed.

Residential, Commercial and Composite Price Elasticities

Research conducted in southern (Las Vegas Valley) and northern (Reno) Nevada (LVVWD, 2016; Rollins, Lott, and Tchigriaeva, 2014) demonstrates how several factors can influence the price elasticity of water demand specific to residential and commercial sectors. Residential refers to single-family (individual residences) and multi-family (apartment buildings, condominiums and manufactured home parks) water users. Commercial refers to manufacturing, retail and other commerce-based water users.

Single-Family Residential Price Elasticity

For single-family residences in arid areas such as Nevada, outdoor water use is the largest and most variable component of water consumption. Outdoor water consumption varies across residences depending on a number of characteristics, including size of turfed area, size of treed area and presence of a swimming pool.

Single-Family Residences in Reno Area. The Reno area climate is classified as high desert with less than 8 inches of rain per year and an annual average temperature of 54.4 F. Reno has an average annual high of 81 F and low of 26 F. The Truckee River Basin supplies water to this area and depends nearly exclusively on annual Sierra Nevada snowpack accumulation and snowmelt runoff (National Weather Service Forecast Office, 2012). The TMWA services the Reno area. Single-family residences in Reno consume, on average, 12.3 thousand gallons of water per month.

Irrigation for landscaping is the primary water use for residential and commercial water users in the Reno area. The irrigation season is from early spring through late fall, during which time water use is four to five times greater than winter use, which represents primarily indoor consumption. Table 1 illustrates how fluctuation in seasonal temperatures and wind speed can influence demand for outdoor water use in the Reno area.

Table 1. Seasonal temperatures and single-family residence price and income elasticities in the Reno area.

Variable	Effect
Fall Temperature (Sept.-Nov.)	An increase of average temperature by 1 F leads to an increase in water demand per household of about 3.8 percent.
Summer Temperature (June-Aug.)	An increase of average temperature by 1 F leads to an increase in water demand per household of about 0.7 percent.
Spring Temperature (March-May)	An increase of average temperature by 1 F leads to an increase in water demand per household of about 3.4 percent.
Wind Speed	An increase in wind speed by one knot increases water demand by 2.6 percent.
Price Elasticity	-0.20
Income Elasticity	For a 1.0 percent increase in income, users respond by increasing consumption by 0.16 percent.

Source: Lott et al., 2014.

The results presented in Table 1 illuminate several characteristics of water demand in the Reno area. Higher temperatures during the fall and spring seasons increase water consumption more than higher temperatures during the winter and summer seasons. This is because temperature largely influences when homeowners choose to turn on (and off) their irrigation systems. A slight difference in temperature can change this decision by several weeks. The price elasticity of -0.20 demonstrates that families are relatively inelastic with respect to changes in the price of water. That is, when price increases by 1.0 percent, single-family residences in the Reno area consume only 0.2 percent less water.

Single-Family Residences in Las Vegas Valley. Table 2 illustrates the effects of outdoor water consumption variables for the Las Vegas Valley and the estimated price elasticity of water demand. Other factors included for estimating price elasticity for this region include climate (temperature, wind speed and precipitation), turf restriction policy, house size (number of bedrooms) and income. The climate in the Las Vegas Valley, in particular, affects water consumption as it is characterized as subtropical desert with extremely high summer temperatures, an average annual temperature of 70.7 F, and an average annual 4.5 inches of precipitation (Sovocool and Morgan, 2006).

Single-family residences in Las Vegas consume, on average, 11.46 thousand gallons of water monthly and represent 45 percent of water consumption in Las Vegas. Water supply for this region comes from the Colorado River Basin, which depends on annual Rocky Mountain snowpack accumulation and snowmelt runoff (National Weather Service Forecast Office, 2012).

Table 2. Single-family residence Las Vegas Valley price elasticity variables and price elasticity estimate.

Variable	Effect
Temperature	An increase of average daily temperature by 1 F leads to an increase in water demand per household of about 0.9 percent.
Wind Speed	An increase in wind speed by one knot increases water demand by 1.4 percent.
Precipitation	An additional day of precipitation decreases water demand by 0.8 percent.
Number of Bedrooms (House Size)	An additional bedroom contributes to a 9.2 percent increase in water demand.
Income	A $1,000 increase in income increases water demand by 4 percent.
Swimming Pools	The presence of a swimming pool increases water use, on average, by 5.9 percent per month.
2003 Turf Restriction Policy	The turf restriction policy implemented on homes built after 2003 decreases water use by 9 percent.
Turf Area	Increasing turf area by 10 square feet increases water use by 0.29 percent monthly.
Treed Area	Increasing treed area by 10 square feet increases water demand by 0.13 percent monthly.
Price Elasticity	-0.34

Source: Rollins, Lott, and Tchigriaeva, 2014.

Table 2 results for single-family residence water demand in the Las Vegas Valley report a price elasticity of -0.34, meaning that a 1.0 percent increase in the marginal price of water reduces the quantity of water demanded by 0.34 percent. "For example, increasing water rates by 10 percent (from a mean of $2.31 to $2.54 per thousand gallons) will decrease water consumption by 3.4 percent, which is on average 408 gallons per month or 4.9 thousand gallons annually per household" (Rollins, Lott, and Tchigriaeva, 2014). Table 2 also shows that restricting the amount of turf per household can be effective in limiting outdoor water use.

Single-family Residences: Contrasts Between Reno and Las Vegas. The seasonality of water consumption in Reno contrasts with that in the Las Vegas Valley. Demand for water during the summer months in the Reno area is four to five times greater than in winter; whereas in Las Vegas, demand during the summer is less than two times the winter demand. The differences in seasonal water use between Reno and Las Vegas underlines the variation in demand that exists due to dissimilarities in climate.

Single-family residences in Las Vegas have a price elasticity of -0.34, and residences in Reno have a price elasticity of -0.20. These elasticities indicate that families in Las

Vegas are more responsive to changes in the price of water. This may reflect that prices are generally higher in the Las Vegas area than in the Reno area.

Multi-Family Residential Price Elasticity

Multi-family residences, such as condominium complexes, apartment buildings and manufactured home parks, represent 19 percent of water consumption in the Las Vegas Valley. For multi-family residences in Las Vegas, water price elasticity is estimated at -0.68. We expect multi-family residential complexes as a whole to be more sensitive to price changes than single-family residences because outdoor water use is generally managed by a private company or by a homeowners' association that is responsible for reporting costs.

Manufactured home parks in the Las Vegas area offer an interesting example. Because the residents of these parks tend to be seniors with lower and fixed incomes, the LVVWD negotiated that the water rates would not increase at higher tiers of use, as is the case for other customers. Water bills tend to be paid by management of these residential parks, who also maintain common areas and landscaping. When faced with increases in water prices, managers are not easily able to pass on increases to their residents. Instead, the increase nudges management to avoid the higher costs by updating infrastructure, such as leaky toilets, outdoor watering and irrigation systems, which can produce substantial reduction in water demand without affecting residents. Therefore, manufactured home parks exhibit a relatively high price elasticity of -1.59.

Commercial Price Elasticity

Commercial water users, such as manufacturing, retail and other commercial businesses, represent 36 percent of water use in the Las Vegas Valley. A survey of literature from various locations in the U.S. reveals price elasticities for commercial users ranging from -0.23 to -0.63 (LVVWD, 2016). The elasticity for commercial consumers in Las Vegas is estimated at -0.61. This value suggests that commercial users are more responsive to price changes than single-family residences. This is likely because profit maximizing firms treat water as an input to production and have a financial incentive to alter production to account for changes in input costs.

Composite Price Elasticity

The composite price elasticity represents the change in water demanded due to a change in water rates by **all** consumers in a given utility service area. To calculate the composite price elasticity for the Las Vegas Valley, the price elasticities of each consumer group (residential and commercial) are weighted by the share of total water consumed by each sector and aggregated to produce a composite price elasticity of -0.51. It is important to note that this estimate of price elasticity is unique to the Las Vegas Valley because the relative elasticities of consumer groups in the area each affect the composite price elasticity of demand for water.

Table 3. Multi-family residence, commercial, and composite price elasticities for water in Las Vegas Valley.

Group	Price Elasticity
Single-Family Residences	-0.34
Multi-Family Residences	-0.68
Commercial	-0.61
Composite	-0.51

Source: LVVWD, 2016.

Conclusion

Estimates of price elasticity of water are imperative for predicting the quantitative impacts of changes in price on consumption, and thus water utility revenues. As reported here, price elasticities and other factors affecting demand for water can vary across regions. Climate and seasonality of water use can substantially influence water demand in southern and northern Nevada. Additionally, it is clear that the characteristics of water users influence their response to changes in price. Finally, it is important for water utilities to use accurate estimates for price elasticities when predicting future revenues necessary to maintain and improve water infrastructure. Utilities using inaccurate elasticity measurements risk financial losses and thus failure in providing adequate services to customers.

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