Economic Water Demand Functions to Value Urban Water Scarcity along Utah's Wasatch Front

Technical Report

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Summary

Representing urban water demands economically is useful to understand how anticipated changes like population growth, conservation, water development, climate change, and environmental water demands may affect water deliveries and scarcity. Utah is the second driest state in the nation, while per capita water use is near the highest in the nation, averaging 167 gallons per person per day. This implies that creative water management will be ongoing in Utah's future. Urban economic loss functions are estimated using residential demand functions for Utah's Wasatch Front Metropolitan Area, which includes Logan, Salt Lake City, Ogden, Layton, Provo, and Orem urban regions. Water price, volume of water applied at that price, urban population, and price elasticity data are presented. Results show seasonal residential water demand functions and seasonal urban (residential, industrial, institutional, and commercial) economic loss functions for Logan, Ogden, Salt Lake City, and Provo metropolitan areas. Limitations to this method are outlined and discussion focuses on estimating urban water demand functions and potential economic losses input into hydro-economic models and ecological-economic models to evaluate promising solutions to Utah's persistent water problems.

Introduction

Valuing water economically constrains water resources management decision-making to evaluate tradeoffs between alternative water uses and provide estimates of economic losses from population growth, climate change, reservoir re-operation, environmental protection measures, and other water management changes (Young 2010). Economic demand functions are often input into hydro-economic and ecological-economic systems models to evaluate whether future water development is warranted, estimate pricing policies on urban water demands, identify potential water markets, and optimize scarce water resources for competing urban, agricultural, environmental, and energy demands (Draper et al. 2003; Harou et al. 2010; Kraft 2017). Economic demands and loss functions are intuitive for water managers and stakeholders because shortages are expressed in dollars and changing water value with increasing water scarcity is estimated. Results suggest prices that residential, commercial, industrial, and institutional water users would be willing to pay for additional water along demand curves.

This report describes methods and assumptions to develop seasonal urban economic loss functions for Utah's Wasatch Front Metropolitan Area. Economic loss functions were estimated using the demand function method (Arbués et al. 2003; Jenkins et al. 2003). Demand functions are assumed to be continuous so that the quantity of water demanded is differentiable with respect to price (Espey et al. 1997). Economic demand and loss functions were approximated for the Logan, Ogden/Layton, Salt Lake City/West Valley, and Provo/Orem urbanized areas (Figure 1), representing 78% of Utah's total population (2,152,000 residents in 2010) (US. Census Bureau 2012).

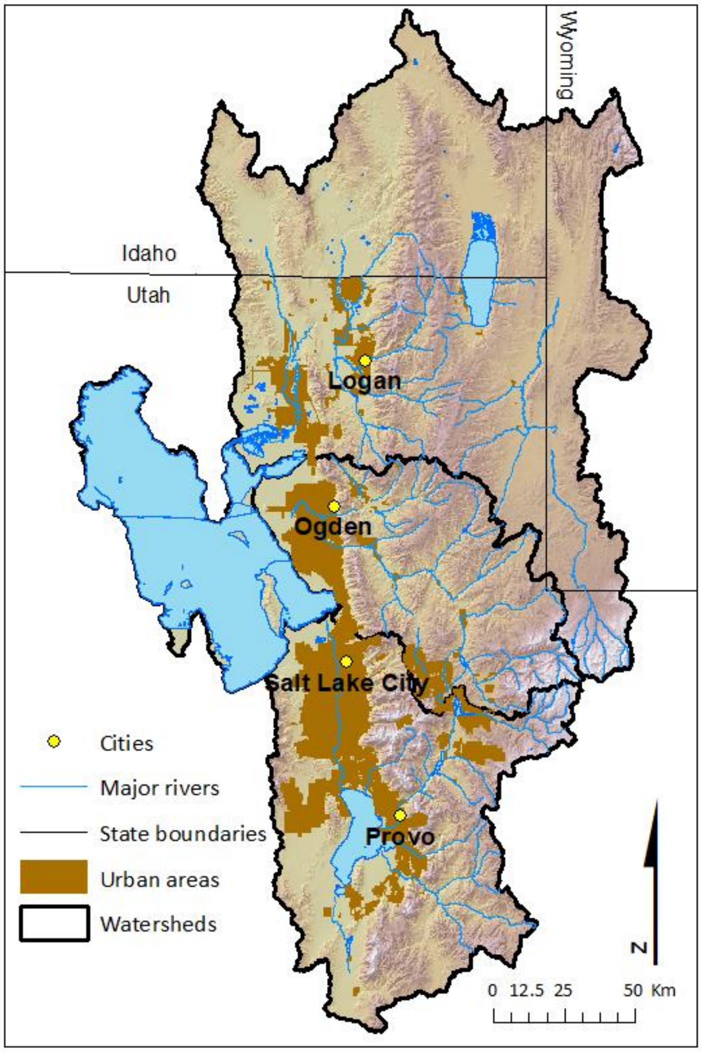

Figure 1. Wasatch Front Metropolitan Region

Methods

The economic demand function approach requires water price, volume of water required at that price, the price elasticity of water demands, and urban population. All estimates use 2010 data for population, water prices, applied water, and urban sector fractions (Table 1). Seasonal price elasticity data for 1999-2002 were available for Salt Lake City (Coleman 2009) and are applied to other urban regions (Table 1). This is common, as statewide estimates are often applied for regional estimates (Jenkins et al. 2003). Coleman (2009) reported Salt Lake City summer water price elasticity was -1.445; however, this value was low compared to price elasticities in other regions and caused seasonal demand curves to intersect. Summer elasticity was increased until seasonal demand curves no longer intersected. Price elasticity estimates applied here are within common ranges. In a meta-analysis of price elasticity of residential demand for water, Espey et al. (1997) reported that price elasticities averaged -0.51 and 90% of the estimates were between 0 and -0.75.

Table 1. Urban economic demand function data and sources (n/a = data unavailable, af = acre-feet, gpcd = gallons per capita per day)

	Logan	Ogden /Layton	Salt Lake City /West Valley	Provo/Orem	Data Source
Population in 2010	96,888	544,969	1,016,219	493,856	(US. Census Bureau 2012)
Weighted average residential water price in 2010 ($/af)	$274.06	$405.08	$484.20	$298.09	(Jackson-Smith, pers. comm., 2015)
Per capita applied water in 2010 (gpcd)	259	235	213	215	(Jackson-Smith 2017)
Total applied water (af)	28,139	143,283	242,253	118,924	Calculated (per capita applied water * population)
Residential fraction (%)	0.65	0.79	0.70	0.69	(Jackson-Smith 2017)
Industrial, Commercial, and Institutional fraction (%)	0.35	0.21	0.30	0.31	(Jackson-Smith 2017)
Residential summer price elasticity	*n/a*	*n/a*	-0.700	*n/a*	Estimated
Residential winter price elasticity	*n/a*	*n/a*	-0.378	*n/a*	(Coleman 2009)
Residential fall/spring price elasticity	*n/a*	*n/a*	-0.485	*n/a*	(Coleman 2009)
Non-residential price elasticity	*n/a*	*n/a*	-0.665	*n/a*	(Coleman 2009)

Population, water price, per capita applied water, and urban sector fractions (residential or lumped industrial, commercial, and institutional water uses) vary by urban region. 2010 population estimates for the Logan, Ogden/Layton, Salt Lake City/West Valley, and Provo/Ogden are from US census data (US. Census Bureau 2012). Water price data for 2010 were compiled from state reports, surveys, and websites (Jackson-Smith, pers. comm., 2015). Population-weighted per capita applied water data are from Utah Division of Water Rights in their annual surveys of public water systems, as are fraction of water use by sector (residential or lumped industrial, commercial, and institutional). Data were cleaned by Utah Division of Water Resources and compiled by Jackson-Smith (Jackson-Smith 2017). These data align with previous statewide estimates of 167 gallons per person per day (gpcd) for residential water users (excluding industrial, commercial, and institutional uses) (Maupin et al. 2014). Per capita water use in Utah is one of the highest in the nation (Office of the Legislative Auditor General 2015).

Results

Residential water demand functions for summer, winter, spring/fall were estimated for Logan, Ogden, Salt Lake City, and Provo/Orem metropolitan areas (Figure 2). These demand functions show the effects of seasonally varying water price elasticities (Coleman 2009). They also reflect varying water price, population, and volume of applied water by metropolitan area. 2010 water prices are included for each region, where marginal changes around historical water demands and supply are most accurate. Curves were extended to cover large water delivery and price changes here, although uncertainty increases along curves farther away from 2010 water prices, and meaningful ranges can be limited when applied in hydro-economic models or other water analyses.

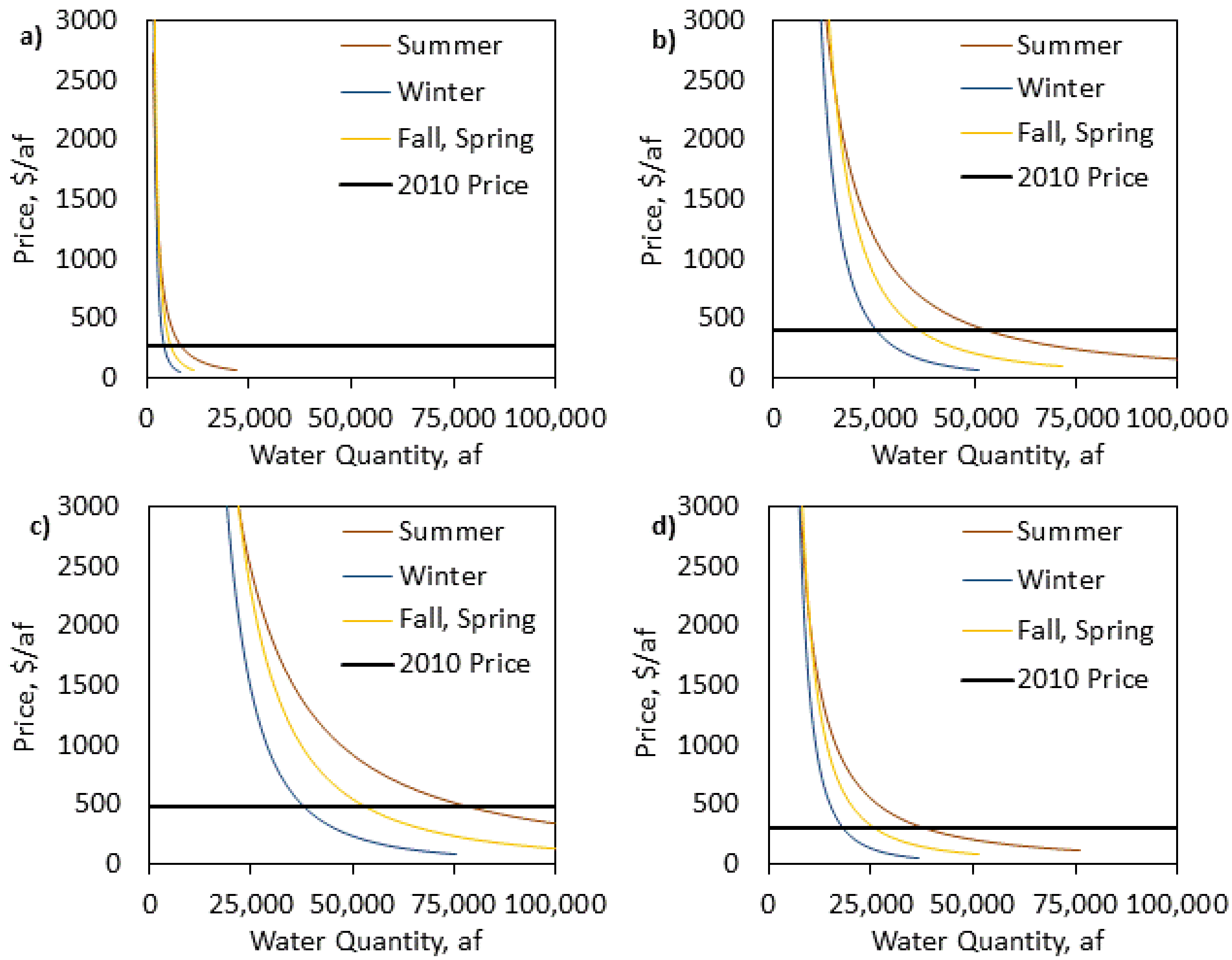

Figure 2. Residential water demand functions for a) Logan, b) Ogden, c) Salt Lake City, and d) Provo metropolitan areas. Water demands vary by season. Summer is May – September, winter is November – March, and fall/spring is October& April (af = acre-feet).

Water prices, applied water, and demands are considerably lower in Logan than other Wasatch Front metropolitan areas, resulting in inelastic urban water demand functions when water prices exceed approximately $1000/af in Logan. Conversely, Salt Lake City / West Valley has the highest 2010 residential water prices and demands, and the largest differences between summer and winter water demands.

Seasonal economic loss functions for combined residential, industrial, institutional, and commercial water use sectors were estimated by integrating the residential demand functions in Figure 2 and adding target demands from the other urban water use sectors (Figure 3). Economic loss functions estimate water losses (in US$ millions) from water scarcity. Water scarcity is the difference between the volume of water demanded and the volume actually delivered. Salt Lake City / West Valley and the Ogden / Layton metropolitan areas have the largest water demands and potential for the largest urban economic losses from water scarcity.

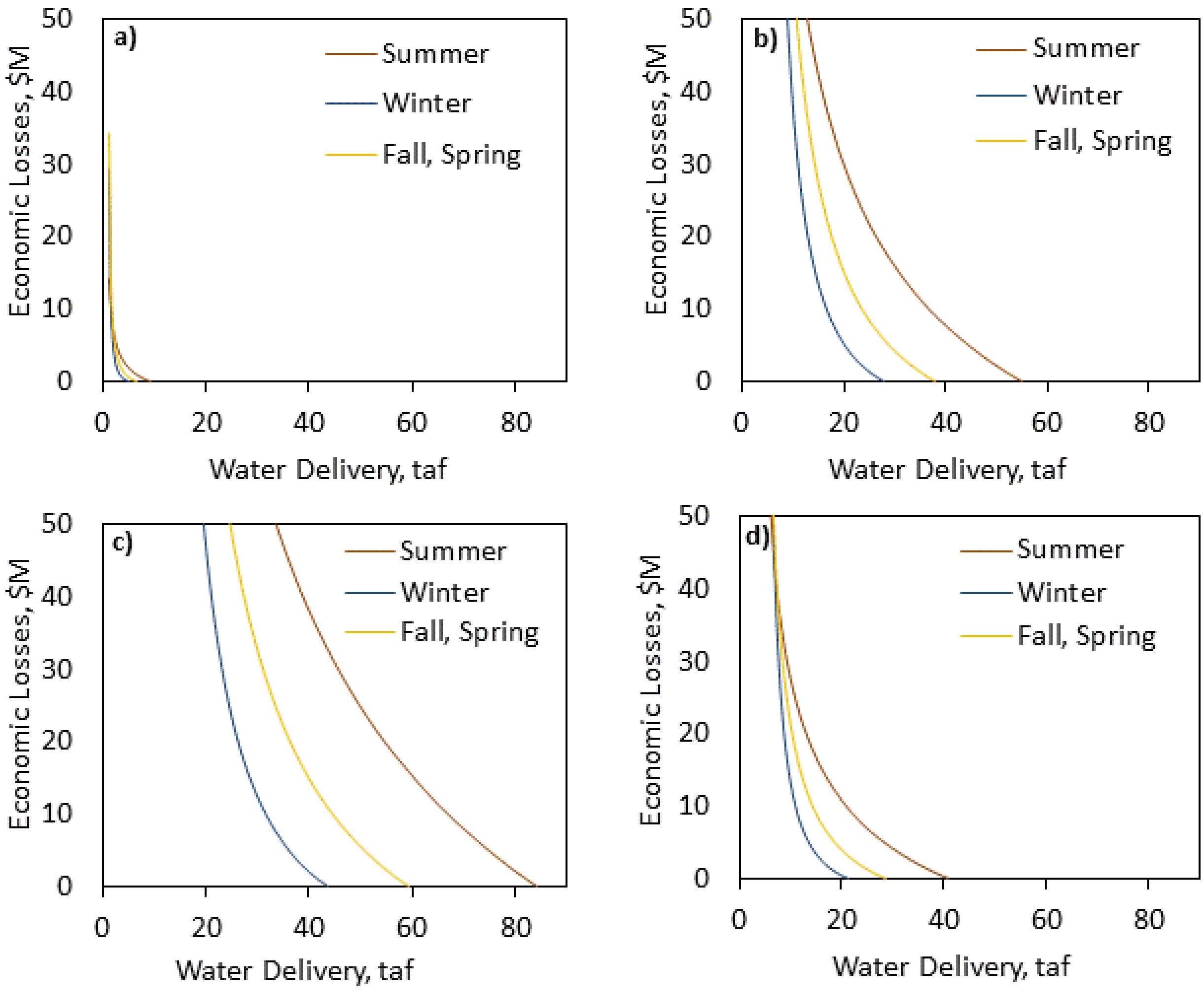

Figure 3. Seasonal residential, industrial, institutional, and commercial economic loss functions for a) Logan, b) Ogden, c) Salt Lake City, and d) Provo metropolitan areas. Water demands vary by season and summer is May – September, winter is November – March, and fall/spring is October& April (taf = thousands of acre-feet, $M = Millions of US$).

Limitations

Water price elasticities are applicable to marginal changes around historical water prices and demands. They can be applied to evaluate marginal changes to water demands, pricing structures, income levels, and other factors that affect urban water price elasticity (Espey et al. 1997). Thus, price elasticities are valid for the 1999-2002 period for which they were estimated (Coleman 2009). However, it is standard practice in hydro-economic modeling to apply water demand functions broadly to estimate water demand and delivery changes from non-marginal changes (Brouwer & Hofkes 2008). Potential non-marginal changes include climate change effects on water supply (Tanaka et al. 2006; Harou et al. 2010), water system re-operation (Null & Lund 2006), effects of new water supplies like desalinated water, recycled water, stormwater, or improved water treatment facilities on water demands (Qin et al. 2011), and increased environmental protection measures on urban water demands (Brouwer & Hofkes

2008). In fact, most observed changes in water supply are non-marginal (Ward 2009). Linear water demand functions are sometimes used because they are easy to develop, although they assume that water demands response is the same regardless of price level and that urban consumers are insensitive to water prices at low price levels (Espey et al. 1997; Arbués et al. 2003). Estimating non-marginal water demand changes using demand functions results in high uncertainty, and provide initial ballpark ranges of water prices and demands. Improved estimates of water price elasticities to enhance estimates.

Economic urban loss functions combine residential, commercial, industrial, and institutional water uses. Aggregating water uses is representative when relationships between prices and water demands are identical (Espey et al. 1997). Aggregating urban water uses is common in hydro-economic modeling of large regions or systems given the unavailability of price elasticities by distinct urban water uses (Jenkins et al. 2003; Brouwer & Hofkes 2008). Finally, in reality, water demands vary not only with price, but also with hydrologic conditions, conservation measures, development of new water supplies, income, and other variables that affect urban water elasticity (Arbués et al. 2003).

Discussion

Estimating urban economic water demand functions using observed price elasticities, water prices, and water demands quantifies how water demands are differentiable with respect to price. Estimates can be input into hydro-economic models to estimate how water supply and demand changes affect water deliveries and water scarcity (Draper et al. 2003) and into ecological-economic models to understand how changing environmental water allocations affect urban water deliveries and scarcity (Kraft 2017).

Along Utah's Wasatch Front Metropolitan Area, these estimates are required to improve aquatic habitat representation in water resources systems models (Kraft 2017), and improve understanding of how population growth, climate change, water development, conservation, and environmental protection affect urban water demands and scarcity (Bardsley et al. 2013; Hale et al. 2015). Estimates can also be incorporated into environmental planning to maintain water deliveries and ecosystems in Utah's iconic Great Salt Lake (White et al. 2015; Wurtsbaugh et al. 2016).

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