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Water demand under alternative price structures

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Abstract

We estimate the price elasticity of water demand with household-level data, structurally modeling the piecewise-linear budget constraints imposed by increasing block pricing. We develop a mathematical expression for the unconditional price elasticity of demand under increasing block prices and compare conditional and unconditional elasticities analytically and empirically. We test the hypothesis that price elasticity may depend on price structure, beyond technical differences in elasticity concepts. Due to the possibility of endogenous utility price structure choice, observed differences in elasticity across price structures may be due either to a behavioral response to price structure, or to underlying heterogeneity among water utility service areas.

JEL classification: Q21; Q25; Q28; L95; D12

Keywords: Water demand; Price elasticity; Non-linear pricing

1. Introduction

Water managers traditionally have maintained that consumers do not respond to price signals, so demand management has occurred most frequently through restrictions on specific water uses and requirements for the adoption of specific technologies. In theory, raising prices to bring about water conservation is less costly than implementing a command-and-control approach, even if the prices in question are inefficient. Water utilities increasingly hear this message and respond in many cases by implementing increasing block prices (IBPs), under which marginal prices increase with the quantity consumed. The price elasticity of water demand is a key variable of interest in this context, because: (1) regulators may use price to reduce demand during periods of scarcity; and (2) utilities often face zero-profit constraints, so the impact of price changes on total revenues is a concern.

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In 2000, approximately one-third of US urban residential water customers faced IBPs, up from 4% in 1982 [31,33]. Consumer responses to IBPs in the market for water are unclear, at best. Estimating water demand functions under non-linear price regimes requires econometric techniques that can separate demand from supply. The problem is that marginal prices change as consumption increases, so that, while the price schedule is set by the supplier, the actual price paid by the consumer and the quantity consumed are simultaneously determined.

Our analysis offers three main contributions to the economic literature on water demand. First, using the most price-diverse, detailed, household-level water demand data yet available, we exploit substantial variation in the price incentives faced by households to estimate price elasticities under increasing block and uniform marginal prices. Using a structural model that accounts for non-linear prices, we estimate a full-sample price elasticity of water demand of approximately -0.33. We are not the first to estimate a structural water demand model for consumers facing piecewise-linear budget constraints. However, previous applications have analyzed very restrictive samples. Ours is more broadly representative of US urban residential water demand.

Second, we explore the ways in which the concept of price elasticity under non-linear prices differs from that under a typical single marginal price. We find that the price elasticity of demand under IBPs is a complex function of the price and income elasticities of demand along particular budget segments. These results may be of some general interest, as non-linear prices predominate in markets for many goods and services other than water, including electricity, local and wireless telephone services, and labor supply under progressive income taxation.

Third, we consider the interesting and policy-relevant possibility that, aside from innate mathematical differences in what price elasticity is measuring, household price elasticity may be a function of a utility's choice of price structure. Our examination of this question is prompted by: (1) some clues in meta-analyses in the water demand literature that suggest this could be the case; and (2) the fact that the three previous applications of structural estimation under non-linear prices have all resulted in high price elasticity estimates, relative to the mean in the literature. We perform two tests of this hypothesis. Results suggest that price elasticity may be a function of price structure. However, there are a number of complications in this determination which are described further below. What we observe may be a behavioral response to price structure, or it may be due to underlying heterogeneity among utilities adopting different price structures.

In large parts of the US, scarce water supplies are a serious environmental concern. In some cases, water is being used at rates that may exceed those dictated by the efficiency criterion, particularly when externalities are considered.[1] Cities in arid states such as Texas and California have struggled to manage scarcity in the face of population growth, as well as consumer demand for swimming pools, landscaping and other water-intensive amenities. The administratively determined rate schedule sets water markets apart from many natural resource markets in which we would expect prices to reflect scarcity (e.g., oil and coal). Nonetheless, public agencies typically set water prices, thus the potential exists for establishment of rate structures that provide social-welfare-compatible incentives. This paper explores two important aspects of water pricing—how sensitive US households are to changes in water prices, and whether price elasticity differs under alternative rate structures. Research in this area can provide critical information to water resource managers.

The paper is organized as follows. In Section 2, we review the literature on block pricing and the price elasticity of residential water demand. In Section 3 we describe our models, and in Section 4 we describe the data. In Section 5 we describe the results, and in Section 6 we conclude.

2. The literature and the economic context

2.1. Block pricing and efficiency

Urban residential water pricing typically takes one of three forms: (1) a uniform marginal price; (2) IBPs; or (3) decreasing block prices. Each of these price structures is typically accompanied by a fixed water service fee. Under a uniform price (UP), households pay a single volumetric marginal price at all levels of consumption. Increasing block structures charge higher marginal prices for higher quantities consumed, resulting in a water

[1]For example, in many parts of the US, annual water use is maintained by groundwater mining [8].