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Design and assessment of an efficient and equitable dynamic urban water tariff. Application to the city of Valencia, Spain

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ABSTRACT

Water pricing policies have a large and still relatively untapped potential to foster more efficient management of water resources in scarcity situations. This work contributes a framework for designing equitable, financially stable and economically efficient urban water tariffs. A hydroeconomic simulation model links the marginal value of water, which reflects water scarcity given its competing uses, to water supply reservoir levels. Varying reservoir levels trigger variations in the second block of the proposed two-block increasing-rate tariff; these variations then reflect water's value at that time. The work contrasts the two-block scarcity tariff with a constant volumetric rate for the city of Valencia, Spain, and the drought-prone Jucar basin, where most of 430,000 households are equipped with smart meters. Results show urban consumption is reduced by 18% in the driest years, lowering basin-wide scarcity costs by 34%.

1. Introduction

Growing pressure on existing water resources from rising demand and uncertain supply underline the value of efficient management strategies. Although urban water conservation is often achieved through prescriptive regulation, the use of prices to manage water demand can be more cost effective than non-price conservation programs (Olmstead and Stavins, 2009). The potential of water pricing to foster more efficient management of available water resources has been recognized in regulatory frameworks such as the EU Water Framework Directive (EC, 2000). This European regulation promote pricing as a way to pursue several objectives such as cost recovery for water suppliers, economic efficiency and environmental preservation by factoring in not only the financial but also the environmental and resource costs (Heinz et al., 2007; Pulido-Velazquez et al., 2008; Brouwer et al., 2009).

A pricing policy is economically efficient if the prices charged correspond to the total marginal cost of water (Rogers et al., 2002). In economic terms, efficient water management abides by the equimarginality principle, whereby the benefit forgone by allocating an additional unit of water to any consumer – also known as marginal resource opportunity cost (MROC) (Pulido-Velazquez et al., 2008; 2013a; Macián-Sorribes et al., 2015), – is the same regardless of the consumer. In lay terms, to achieve the greatest return from existing water resources a supplemental unit of water should be valued equally by different consumers. Yet, even though water pricing can in theory pursue several objectives at once including economic efficiency, its practical implementation can prove challenging because other objectives might have to considered for price design. This is the case for urban water rates that are expected to meet some basic functions (Hanemann, 1998; Griffin, 2006; Barberán and Arbués, 2009). Cost recovery is a priority, as the selected tariff has to provide sufficient revenues to allow the utility to recover the cost of supply and meet its financial obligations, in both short-run and long-run conditions. Other objectives of urban water tariffs refer to the way costs should be allocated among consumers. Water rates should ideally be perceived as affordable, fair and equitable by the consumers. Finally, the proposed rates should be easily understood by clients and utilities and legally acceptable. An example of residential urban tariff design that considers efficiency, equity, financial cost recovery, public acceptability and transparency is proposed by Garcia-Valiñas (2005). The method characterizes the urban water

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demand using an econometric approach, and the costs of water supply through a Cobb-Douglas function. A variety of tariffs was then evaluated in terms of welfare effects, using the consumer surplus as indicator. The approach assessed economic efficiency and financial considerations but only at the consumer and utility levels, whereas the consequences of urban tariffs on consumption have repercussions on water availability and scarcity for all consumers in a river basin.

Rate design is also constrained by the metering technology, which determines how regularly consumption can be measured. For instance, without water meters, customers are charged a fixed rate, which provides no incentive for consumers to know their consumption (Whittington et al., 2002). With ordinary meters, water can be charged at a volumetric rate. Flat rates can be efficient if well-designed (Garcia and Reynaud, 2004; Dige, 2013). Decreasing block rates, which lead to high volume consumers paying lower average water prices, has gradually fallen out of favor (Whittington et al., 2002). In contrast, increasing block rates (IBR) that penalize heavy consumers have become widely implemented, because they are seen as fairer and more economically efficient (e.g., Martins and Fortunato, 2007; Chen and Yang, 2009; Madhoo, 2011; Ward and Pulido-Velazquez, 2009). Yet, these merits of IBR have been questioned (Boland and Whittington, 2000; Strong and Goemans, 2014; Whittington et al., 2015), suggesting that when metering technology constrains rate design, pricing schemes may not always achieve their stated objectives. One option is seasonal IBR, that aims at reining in consumption during summer months in places where high summer use puts a strain both on scarce water resources and/or on the distribution infrastructure (e.g. Hoque and Wichelns, 2013; Molinos-Senante, 2014). New smart metering technologies, with their frequent and automated consumption measurements, enable dynamically varying tariffs, i.e., water pricing policies that changes over time. This includes seasonal pricing, but also peak-pricing strategies within a day (Rouge et al., In press). Sharing this information with customers could help manage residential demand (Rizzoli et al., 2014; Cardell-Oliver et al., 2016). Through real time information on water consumption, consumers can get learn about their water use and its associated cost, which has been shown to lower consumption (Gaudin, 2006; Strong and Goemans, 2015). Through real time information on water consumption, consumers know how much water they are using and how much they are going to pay, and how far are them from moving to the next block. Furthermore, prepayment water meters can be considered as a tool to manage water resources that benefit both consumers and utilities. These water meters allow reducing financial and operational costs for the utilities; and allocating the resources more efficiently. However, their implementation could be difficult for low income consumers (Casarin and Nicollier, 2010).

Scarcity pricing has its origin in the fact that, unlike in power networks, water distribution systems rely on largely climate-driven natural supplies. As water becomes scarce, its marginal value increases, and scarcity pricing aims to reflect this. When the supply is abundant, this value is essentially zero and water price at the tap only reflects the treatment and delivery costs. When water becomes scarce, scarcity pricing adds the opportunity costs in the allocation of the scarce water to the price of water at the source that promotes an economically efficient allocation (Pulido-Velazquez et al., 2013a; Riegels et al., 2013; Griffin, 2006). This efficient scarcity price at source is the same for all other sectors, such as agriculture, industry, etc.

However, water scarcity pricing has been very rarely implemented. In California, the 2012–2016 drought spurred the implementation of economic tools such as drought surcharges and penalties to reduce residential water use. 29% of water utilities used drought surcharges (Mitchell et al., 2017): an increase in the unit price of water triggered by low water supply levels. During the same period, up to 79% of utilities used penalties: fines charged to those that do violate water restrictions. These instruments have served to decrease water use while increasing revenues in periods when lower water use reduce revenues considerably, functioning as economic and financial tools at the same time. Mitchell et al. (2017) found that drought surcharges were significant in reducing per capita water use and complying with conservation targets. Previous studies have analysed the impacts of applying temporary drought pricing (e.g. Sahin et al., 2015, 2016) on urban systems. These pricing policies are only applied during drought periods, and the escalation of the baseline price schedule is based on the storage (price increased in a percentage with respect to the normal price, based on certain critical storage levels). But those prices are not linked to the marginal economic value of water in the system.

In this paper we present a novel method for the design and assessment of economically efficient, equitable and financially-stable urban water rates considering a scarcity price, based on the estimation of water's value at basin scale over time. Rates are dynamic in the sense that they vary every year according to the estimated marginal value of water, which is linked to water scarcity and water demand. The urban water tariff is designed to transfer marginal water values at river basin scale to consumers, while considering the required conditions of urban water rates. As such, they are a first step towards exploiting the combined use of economic basinwide water resources assessment and urban smart metering technologies for designing economically efficient water tariffs.

2. Methods

2.1. General overview

The proposed three-staged framework aims to design a dynamic urban water tariff considering the changing value of water (throughout the river basin and over time) for achieving more efficient water use. The first stage consists of obtaining a scarcity-based step pricing policy at river basin scale via use of time series of water value estimated throughout the basin. The second stage is the design of a baseline water tariff at consumer level taking into account the revenue sufficiency and equity criteria. Finally, the third stage is the dynamic urban water tariff using as a basis the scarcity-based pricing policy at river basin scale (stage 1) and the baseline water tariff at consumer level (stage 2). An increase block rate has been chosen to design the dynamic urban water tariff.

2.2. Marginal value of water at source

The marginal value of water is used to get the scarcity-based water pricing policy. It can be estimated using hydro-economic models (HEMs) that use willing-to-pay estimates ('demand curves') for each water user within the water resource system. HEMs allow for an integrated analysis of water supply, demand and infrastructure management at basin scale (Pulido-Velazquez et al., 2008, 2014; Harou et al., 2009; Heinz et al., 2007; Bauer-Gottwein et al., 2016).

In this work, time series of marginal value of water at different reservoirs in the system were determined through a priority-based simulation model that accurately reproduces complex system features, such as priorities in water allocation and system operating rules. The model was developed using the Decision Support System (DSS) SIMGAMS, a generic tool for developing hydroeconomic simulation models (Pulido-Velazquez et al., 2013b; López Nicolás,