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Evaluating the Performance of Alternative Municipal Water Tariff Designs: Quantifying the Tradeoffs between Equity, Economic Efficiency, and Cost Recovery

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Summary. — The design of municipal water tariffs requires balancing multiple criteria such as financial self-sufficiency for the service provider, equity among customers, and economic efficiency for society. A modeling framework is developed for analyzing how alternative municipal water tariff designs affect these three criteria. It is then applied to a hypothetical community in which a municipal water utility provides metered, piped water, and wastewater services to 5,000 households. We analyze how the shift from a uniform volumetric tariff to different increasing block tariff (IBT) designs affects households' water use and water bills, and how these changes in turn affect measures of equity and economic efficiency for two different financial self-sufficiency targets. We calculate how changes in assumptions about (1) the correlation between household income and water use, and (2) households' response to average or marginal prices affect the tariffs' performance in terms of these three criteria. The results show that IBTs perform poorly in terms of targeting subsidies to low-income households regardless of the magnitude of financial subsidies that a utility receives from high-level government. When cost recovery is low, the distribution of subsidies under IBTs is even worse if the correlation between water use and household income is high. IBTs introduce price distortions that induce economic efficiency losses, but we show that these welfare losses are relatively small, especially when households respond to average prices.

Key words — tariff design, increasing block tariffs, water pricing, subsidy incidence, subsidy targeting

1. INTRODUCTION

There are many reasons to get water prices right. Increasing water scarcity and climate change now need to be added to the list. Climate change in particular presents water and wastewater utilities with a complex new set of management and strategic challenges. One important way for water utilities to deal with the uncertainty introduced by climate change is to maintain cash reserves that can be deployed to address problems as they arise. But few water utilities generate sufficient cash to cover their full costs, and typically are unable to invest to protect strategic capital assets from extreme events or to build new capital facilities to address changes in rainfall and streamflow variability.

It is thus increasingly important for water utilities to adopt financially and economically sound water tariff designs that enable them to reliably provide essential services to their customers. This requires that water utilities have access to the expertise to understand how tariff reforms will affect water use, revenues, and capital investment needs, and how these in turn affect the multiple criteria that are used to assess the performance of water tariffs. This capability to model carefully the full array of consequences of a tariff reform process is currently not well developed in either water utilities themselves or in the community of consultants who support them.

In this paper we build upon and modify a simulation model first used by Whittington, Nauges, Fuente, and Wu (2015) to assess how subsidies are distributed across households under an existing increasing block tariff (IBT) structure. In this paper we expand upon our prior analysis to examine the consequences of a change from an existing uniform volumetric price (UP) tariff structure to an IBT, and to estimate how this tariff reform would affect three objectives: equity, economic efficiency, and cost recovery. Our purpose is to develop a better understanding of the trade-offs between these three objectives for different water tariffs. It is widely recognized that the design of municipal water tariffs requires balancing multiple objectives such as financial self-sufficiency for the service provider, equity (especially for poor households), and economic efficiency for society. However, the actual trade-offs between these competing objectives are rarely quantified for policy makers. As a result, policy makers typically do not have a clear picture of the choices they face. They are thus forced to rely on their intuition to judge these trade-offs.

As in Whittington *et al.* (2015), we rely on hypothetical (simulated) data for a population of 5,000 households, and assume that water use and income across the population can be best represented by log-normal distribution functions. We use simulated data instead of real data for three reasons. First, household data sets that combine accurate information on household water use and monthly water bills with information on household income are rare (Whittington *et al.*, 2015). Second, the large number of datasets and studies on residential water demand around the world, as well as numerous income studies, provides sufficient information to calibrate distributions of water use and income among a hypothetical population of households connected to the piped water distribution

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system. Third, simulated data allow us to study a range of IBT designs and to check how their performance in terms of equity and economic efficiency is affected by characteristics of the IBT, including the size of (i) a positive, fixed charge, (ii) the first (lifeline) block, and (iii) the price in different blocks.

We do not claim to identify a tariff structure that finds the optimal balance between the three objectives that are the focus of this paper (cost recovery, equity, and economic efficiency). [1] Rather we analyze how the shift from a UP tariff to different IBT designs affects households' water use and water bills, and how these changes in turn affect measures of equity and economic efficiency for different cost recovery constraints.

The analysis of a shift from a UP tariff to an IBT necessitated making assumptions about how households would respond to changes in prices (i.e., households' price elasticity of demand), which is an important difference compared to the analysis in Whittington *et al.* (2015). We also make assumptions about the costs of services, household income, and household water use that are similar to many cities in industrialized countries. Our analysis is also applicable to cities in developing countries where households have metered, piped connections, but assumptions about the magnitude of some parameters such as household income and costs of services would need to be adjusted to more closely reflect local conditions.

We model a shift to an IBT because IBTs are currently the most popular tariff structure used by water and wastewater utilities globally. [2] A common argument in favor of IBTs is that charging large water users a higher volumetric price (in higher blocks) allows utilities to provide a minimum quantity of water to some households at a reduced volumetric price in the lower, "lifeline" block. Households that benefit most from this reduced volumetric price use small amounts of water, and are commonly thought to be the poorest. However, for this cross-subsidization from rich to poor households to happen, two conditions are necessary. First, low-income households should use less water than high-income households. Second, the volumetric price that is charged in the higher blocks should be above average cost. If all the volumetric prices in the IBT structure (from the lowest to the highest block) are below average cost, then all units of water, whether sold to small or large users, will be subsidized. As a consequence, those who consume more water will receive more subsidies, a situation that is inconsistent with the objective of targeting subsidies to the poor if poor households use less water than rich households.

It is thus surprising to observe the widespread use of IBTs by utilities in cities where these two conditions are not likely to be met. The idea that households with low water use are poor and large users are rich has been challenged for a number of years, starting with Boland and Whittington (2000). Recent empirical evidence on the correlation between water use and income indicates that the correlation is positive but small (Whittington *et al.*, 2015), which is consistent with findings that the income elasticity of residential water use is positive but small. [3] As far as the level of price is concerned, utilities (even in industrialized countries) are rarely covering their full costs and water is often subsidized, even in the higher blocks (Reynaud, 2016).

We argue that a water tariff structure (e.g., an IBT) performs better in terms of equity if it delivers a larger share of total subsidies to the poor, which we define in our calculations as households falling in the first quintile of the income distribution. Because IBTs involve a distortion from efficient pricing (which is achieved in the reference scenario based on a UP tariff structure), we present the trade-off between equity and economic efficiency, the latter measured by the deadweight loss that results from the implementation of the IBT. [4,5] Finally, the financial cost recovery objective is taken into account through two constraints imposed in our simulation model: 100% cost recovery and 50% cost recovery. We ignore other objectives that water utilities may consider in the design of water tariffs, such as revenue stability and water conservation.

We find that IBTs perform poorly in terms of targeting subsidies to low-income households regardless of the magnitude of financial subsidies that a utility receives from high-level government. We also show that when cost recovery is low, the distribution of subsidies under IBTs is even worse if the correlation between water use and household income is high. IBTs introduce price distortions that induce economic efficiency losses, but we show that these welfare losses are relatively small, especially when households respond to average price.

This study adds to the empirical literature on subsidy targeting in the water sector. A number of authors have investigated how IBTs perform in terms of distributing subsidies to the poorest households but fewer have considered the trade-off between redistribution and economic efficiency. Borenstein (2012) asks similar questions for the residential electricity sector. He explores trade-offs between wealth transfer and economic efficiency using household billing data provided by three large Californian electric utilities combined with block-level income data provided by the United States Census Bureau, and finds that IBTs for electricity do redistribute income from wealthier to poorer households but that transfers are fairly modest in comparison to substantial losses in economic efficiency.

2. BACKGROUND

Policy makers and water professionals often rely too heavily on their intuition to assess how changes in water tariff regimes affect financial self-sufficiency, equity, and economic efficiency. Quantitative assessment of these impacts requires the specification of a set of nonlinear relationships with numerous parameters, and then formal simulation procedures to analyze how changes in the tariff structure and price levels affect outcomes of policy interest. Intuition is an unreliable guide for understanding the behavior of systems of nonlinear equations.

Policy makers often make implicit assumptions about both the parameters in this system of nonlinear equations and the functional relationships themselves. Three parameters in this system of nonlinear equations have received insufficient attention; they stand out as both important to the outcomes of a tariff reform process and often uncertain in a particular local setting.

(a) *Correlation between household income and water use*

The first is the correlation between household water use and income. Water professionals typically assume that the correlation between household income and water use is high, i.e., that rich households use more water than poor households. There is, however, surprisingly little empirical evidence reported in the literature to support this assumption. To address this gap, we gathered household surveys from both developed and developing countries, and estimated the correlation between income and water use (measured here by the Spearman's ρ). We do not argue that this is a representative sample of households in either developed or developing countries, but