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Metrics and Methods for Comparing Water Utility Rate Structures*

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Utility managers must design rate structures that meet multiple objectives: full cost recovery, fairness, economic efficiency, and resource conservation. To reach these multiple goals, the design of an optimal rate structure would ideally include detailed information on cost of service, demand elasticity, and preferences of the customer base within each utility. However this information is often unavailable, especially when analyzing utilities at regional or national scales. In this absence, the comparison or benchmarking of rate structures across utilities may reveal insights regarding the features, management, or performance of one utility relative to another. We review the metrics and methods available to water utility managers for comparing rate structures with publicly available information. By presenting the full range of metrics available to utility managers, we aim to facilitate the comparison of water rate structures, and ensure that the analysts can select the metric that best fits their needs. To illustrate how these metrics may help generate insight, we use them to compare the rate structures of five municipalities in Canada. Despite the contextual differences, we find that the rates tend to converge at a single metric, the Canadian standard of 25 m^3/month, suggesting that there is a "looking over the shoulder effect" in which managers are probably cognizant of the metrics used to compare them to others. We suggest that the design or re-design of rate structures can be informed by the metrics that compare rates across utilities, despite the limitations of working with only publicly available information.

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1. Introduction

Water rates provide utility managers with an essential tool to meet multiple objectives such as cost recovery, economic efficiency, water conservation and the equitable treatment of users (Dinar 2000; Rogers *et al.* 2002; Barberán and Arbués 2009). As a result, utility managers must inevitably confront trade-offs. To balance competing goals, water managers can select from a diversity of rate structures and pricing strategies. In volumetric rate structures, utility managers must make decisions about unit charges, the presence of a fixed charge, and the potential size of volumetric blocks. These choices usually require detailed information about the community being served. Each utility must consider its particular water source, treatment costs, consumer preferences, housing types, and geographic conditions (Renzetti 1999; Thorsten *et al.* 2009).

Economic theory suggests that rates should be designed to ensure economic efficiency and full cost recovery (Kayaga and Smout 2014). However rate structures rarely, if ever, are chosen based on economic criteria alone, and empirical research has found that the determinants of water rate structures include factors other than costs of service (Thorsten *et al.* 2009). In Canada, an econometric analysis of 899 communities found that choices in rate structure were based on efficiency and equity goals (Reynaud *et al.* 2005).

Local conditions and political values may also influence choices in rate structure. Utility rate structures are subject to political constraints that may limit the speed or magnitude of tariff reforms (Dinar 2000). Elected officials may have an incentive to defer rate increases for fear of political backlash. As a result, choices about utility tariffs are informed by technical analysis and political criteria. In a review of rate structures in Spain, researchers found that the tariff could be related to the political inclination of the municipal council, even when controlling for physical and operational conditions (Martínez-Espiñeira *et al.* 2012).

There is also evidence that municipal rate structures tend to cluster spatially, and that decisions in one municipality may influence decisions in other municipalities (Thorsten *et al.* 2009; Chica-Olmo *et al.* 2012). This suggests that there is a "looking over the shoulder effect". Accordingly, we expect decision-makers to be vigilant of what is happening in neighbouring communities. Politically, it is difficult to propose changes that do not align with local norms or practices. As a result, utility managers will be interested in understanding how their municipal rate structure compares to others, in their region, province, state or country. Rate comparisons may also be useful when the utilities have not updated their rates for some time. Benchmark comparisons may also be useful for framing discussions about potential pricing reforms (Berg 2007).

Cross-utility comparison, or benchmarking, is a technique commonly used to assess the performance of utilities providers to estimate productivity improvements and set rates (Berg 2010). A well-known example of this in the water sector comes from the United Kingdom, where regulators pioneered the price-cap regulatory approach in order to estimate productivity improvements of water service provides (Gómez-Ibañez 2003). However, the literature on water utility benchmarking often focuses on economic efficiency (Berg and Marques 2011), or performance (Nafi *et al.* 2015) and not on rate structures. Even when authors use multi-criteria analysis (Silva Pinto and Cunha Marques 2016), rates structures tend to be summarized with a single metric, rather than a combination of metrics.

One should proceed with caution when making direct comparisons of rate structures across different systems (Martínez-Espiñeira *et al.* 2012). Differences in context and consumer base may explain variation in rate structure choices. Yet despite these differences, all rates structures send signals to consumers about water use, and all rate structures have strength and weaknesses in terms of equity and efficiency. Thus, while one should not judge a particular rate structure without understanding the particularities of its circumstances, comparisons may still illustrate how utility managers are prioritizing some issues over others. Note that while benchmarking is usually associated with comparisons across utilities, managers may also use metrics for internal analysis to understand how a rate structure affects different stakeholders or the signals it sends consumers.

In this paper, we review the metrics available to utility managers to compare water rate structures. By presenting the full range of metrics available to utility managers, we aim to facilitate the comparison of water rate structures, and ensure that the analysts can select the metric that best fits their needs. Our review focuses on metrics that may be derived from the rate structure alone, and we assume that information about costs or demand is unavailable. Our approach relies on realistic conditions, since rates schedules are usually public information, whereas cost information is internal to each water utility. To illustrate how these metrics may help generate insight, we use them to compare the rate structures of five municipalities in Canada.

2. Method

We reviewed the relevant English academic literature with the aim of identifying the metrics used to summarize a rate structure or compare rates across jurisdictions. We focused on seminal papers and literature reviews, but also examined newer literature. Since our aim was merely to uncover the most frequently used metrics in this literature we did not perform a systematic review of the literature. We reviewed

Table 1. Summary of Water Utility Rate Metrics, Strengths, Limitations and Frequency of Use in Papers Reviewed. Very Common: +10 Papers. Common: 5–9 Papers, Rare: <4 Papers. (Total Papers, 27)

Objective	Metric	Definition	Strengths	Limitations	Usage
Descriptive	Rate type	A broad categorization that describes if a rate structure is volumetric or flat and the type of volumetric structure (IBR, CUC, DBR)	A clear and general description that provides context	There other type of water rate structure, like seasonal, water budget that are not captured with this classification Does not give information on price levels	Very Common
	Charge at a consumption level	Total charge at a reference consumption level	Allows for easy benchmarking across jurisdictions	No consensus on which consumption level should be used	Common
	Charge at average consumption level	Total charge at the average consumption level of the community	Identifies the charge of a user with an average consumption level, and may be more representative of that particular community	Average consumptions values will differ across jurisdictions and consumption information is needed to estimate	Rare
	Average water charge	The average water charge among all users	An average charge for the entire community of users	Average charges will differ across jurisdictions and needs billing information	Rare
	Average charge per unit	Total charge in a billing period divided by volume consumed	Easy to understand and to calculate	It is unclear if this metric is relevant to the user There are different definitions used in the literature	Common
Efficiency	Marginal price	Charge that a consumer pays for on additional unit of water	Highly relevant to economic theory	Users are unlikely to be aware of their marginal price	Very Common

Table 1. (*Continued*)

Objective	Metric	Definition	Strengths	Limitations	Usage
Cost Recovery	Fixed charge	Sum of all minimum charges, base charges and/or fixed fees	Allows for comparison, in absolute terms, of how aggressively the rate structure aims to recover costs and ensure revenue stability	As an absolute value, this metric does not show if the fixed charge is large or small relative to the total charge.	Common
	Percent fixed charge	Fixed charge expressed as a percent of the water bill	Allows for comparison in percentage terms, of how aggressively the rate structure aims to recover costs and ensure revenue stability	As a relative metric, it depends on a reference consumption level.	Rare
Equity (Affordability & Fairness)	Lifeline volume	Volume of water available for the first of block of a rate structure	Especially relevant when designed for low income households May reveal how much water is viewed as essential for a household	Only applies in increasing block rate structures It should be presented in conjunction of the corresponding charge	Common
	Lifeline charge	Corresponding charge for the lifeline volume	Especially relevant when designed to provide low income households with basic needs at a low cost	Only applies in increasing block rate structures	Rare
	Charge to meet basic needs	Charge of a reference volume. The reference volume is calculated to represent the minimum water requirement of a household	It allows for comparisons among jurisdictions	Although there are reference values for minimum water requirements, they vary per household size, geography, etc.	Rare

Table 1. (*Continued*)

Objective	Metric	Definition	Strengths	Limitations	Usage
	Percent of household income	Given a reference income and water consumption levels, it is the total charge of that consumption expressed as a percentage of the income	Allows for comparison among jurisdictions Contextualizes the total charge relative to income	No consensus on which reference levels to use	Common
	Charge per person	Total charge divided by the household size	Describes how fair the rate structure is among households of different sizes	Data needed on household size	Rare
Water Conservation	Rate steepness	Percentage increase or decrease of the total charge relative to a reference consumption level	An intuitive measure of the price signal sent to consumers Can show how fixed charges mitigate incentives for water conservation	A relative measure and therefore changes over consumption volumes	Rare
	Billing frequency	Number of bills the user receives per year	Provides context and may signal administrative capacity	This metric does not show information on the water rate itself	Rare
	Charge at last block	Total charge at the last block	Highlights the strength of the penalty signal sent to users to encourage water conservation	Only applies to increasing block rates The size of the last block varies per jurisdiction	Rare
	Consumption level most expensive block	Consumption level at which a consumer enters the most expensive block	Shows the consumption level which the utility considers excessive	Only applies to increasing block rates	Common
	Number of blocks	Number of block in a volumetric water rate	Shows the complexity of a rate structure	Does not show actual charges	Common

Table 2. Characteristics and Rate Types of the Selected Municipalities in British Columbia, Canada

City	Area (km^2)	Population	Median HH Income (2010)	Liters Per Capita Per Day (LPCD)	Household Consumption (m^3/month)	Rate Type
Abbotsford	376	141,397	$59,984	197	15.9	Constant unit charge
Chilliwack	262	82,918	$54,403	310	22.5	Constant unit charge + Minimum charge
Nanaimo	91	90,504	$51,118	n/a	n/a	Increasing Block Rate + Base charge
Vancouver	115	640,469	$52,855	264	19.4	Flat
West Vancouver	87	42,119	$77,214	444	33.3	Increasing Block Rate + Base charge

the literature and compiled metrics until no new metrics were found. We then organized the metrics by objective or purpose, and considered how authors used each metric, with careful attention to how the use or applications of the same metric might differ across papers (Table 1).

We then turned to a database of municipal water rates collected as part of the 2016 British Columbia Municipal Water Survey which includes the complete rate schedule for 45 municipalities (Honey-Rosés *et al.* 2016b). We chose five municipalities as an illustrative comparison. The chosen municipalities vary by size, median income, water use, and degree of urbanization, and other critical contextual information (Table 2).

3. A Review of Metrics for Water Rate Comparison

In this section we review metrics frequently used to describe and compare rate structures (Table 1). We also aim to help standardize definitions and avoid confusion in interpretation. We begin with descriptive metrics that provide an overview of the rate structure. We then organize the remainder of the metrics and discussion around four common goals for utility managers: economic efficiency; cost recovery; equity and accessibility; and water conservation. Our categorization of each metric is not exclusive, since some metrics may reveal insight on multiple issues. Nevertheless, we find it a convenient way to organize the discussion, especially since metrics are calculated with a purpose in mind, and without context, they may be meaningless. We focus on the residential or domestic sector. For each metric we describe its calculation, use, and interpretation.

3.1. *Descriptive metrics*

3.1.1. *Rate type*

At the most basic level, water rate structures are one of two types: flat or volumetric. Flat rates charge the same price to all users, regardless of actual water consumption. In volumetric rate structures, the total price varies according to the volume of water consumed. Rate type may be a proxy for estimating if a community has water meters, since meters are a necessary condition for volumetric rates. Communities transitioning to water metering may have a mix of both rate types.

Volumetric rate structures have two elements: a fixed charge and a volumetric charge. The volumetric charge is based on the unit price that can be constant, increase, or decrease across consumption levels, producing a *constant unit charge* (CUC), an *increasing block rate* (IBR), or a *decreasing block rate* (DBR) respectively. Some utilities combine an increasing block rate followed by a decreasing block rate to provide low cost water to industries who consume very high volumes.

Water utilities are moving toward the adoption of IBR (OECD 2002; Hoque and Wichelns 2013). In theory, increasing block rates provide a disincentive for wasteful water use (Dinar 2000). However, there are concerns about the fairness and efficiency of IBR (Sibly and Tooth 2013; Schoengold and Zilberman 2014) especially since poorer households tend to be larger, and therefore disproportionately pay more under this rate structure (Barberán and Arbués 2009).

Further, flat or volumetric rates can overlook that some utilities may apply seasonal charges (Olmstead and Stavins 2009), may vary the rates for users based on their economic condition or geographic location (Feldman and Gonen 1975), or may have *water budgets* (Baerenklau *et al.* 2014).

3.1.2. *Charge at a consumption volume*

A common metric used for comparing water utilities is the *charge at a consumption volume*. This metric is popular because it is simple to calculate and does not require billing information. It is frequently used to quantify the range and variability of water bills across multiple water utilities, regions or countries.

The *charge at a consumption volume* is also used as an input in a variety of modeling efforts. For example, it has been used to identify what factors other than cost are used to effect rate structures (Gibbs 1978). Recent comprehensive reviews on water demand modelling can be found in House-Peters and Chang (2011) and in Arbués *et al.* (2003).

The major drawback of this metric is the difficulty to reach consensus on what household volume should be selected for the consumption level making it hard to compare across different contexts in which the underlying consumption levels are likely to differ. For example, the OECD uses 15 m^3/month (OECD 2009), others 20 m^3/month (Hoque and Wichelns 2013), while in Canada, the federal government uses 25 m^3/month (Environment Canada 2011). Martínez-Espiñeira *et al.* (2012) used several consumption volumes (5, 10, 15, 20 and 25 m^3) in order to give a more complete overview. The appropriate volume is the one that most closely approximates the consumption of the user base. However, these consumption values may differ in different contexts.

3.1.3. *Charge at average consumption*

The *charge at average consumption* is what a user pays at the average level of consumption in a particular community. The average consumption is calculated with the total residential water use divided by the total number of residential connections. One then estimates the charge for that average level of consumption. This metric might be a useful alternative to the *charge at a specific consumption volume* if one has reason to believe that a benchmark consumption level (25 m^3/month) is too high or too low for the community being examined, and water use data is available.

While this metric is often used, it can be easily be confused with *the average water charge* (see below). The *charge at the average consumption* has two shortcomings: first, since each community has a different average consumption, this metric is less useful for comparing different systems; and second, in a non-linear tariff scheme (IBR, DBR), the charge at average consumption may underestimate or overestimate the charges the households actually faces.

3.1.4. *Average water charge*

Analysts may also compare rate structures by using the *average water charge*. The *average water charge* is simply the average water bill of all customers. Obviously, the average water charge can only be obtained with billing data. The *average water charge* can be confused with the *charge at average consumption* (see above). These two metrics are likely to be similar but not identical. For example, the average water charge will be higher than the charge at average consumption with an increasing block rate, and lower with a decreasing block rate.

When comparing the *charge at average consumption* and the *average water charge*, the latter seems a more robust metric since it accounts for real bills paid by consumers. Some authors have suggested that the *average water charge* should be calculated for specific users groups, by household size or income (García-Valiñas *et al.* 2010).

3.1.5. *Average charge per unit*

In each billing period, water users confront an average charge for the volume consumed. This average charge, often referred to as an average price, is the total charge in a billing period divided by the volume consumed. The average charge will vary per billing period because it is sensitive to consumption. Even with a flat fee, the average charge will drop as consumption rises.

Some authors calculate the average charge per unit without considering the fixed charge (Wichman 2014) causing some variation and possible confusion. Others estimate the average charge per unit at the utility level, using total revenue divided the total water sales (Taylor *et al.* 2004), rather than at the household level.

The average charge (average price) is often used in economic and demand modelling (Arbués *et al.* 2003; Hoque and Wichelns 2013) and elasticity estimates (Dalhuisen *et al.* 2003). The assumption is that consumers are responsive to the average charge, although this remains under dispute (Taylor *et al.* 2004; Nataraj and Hanemann 2011; Wichman 2014). In a seminal piece on this subject, Gibbs (1978) argue that residential consumers are more likely to react to the marginal rather than to the average price. As a counterpoint, Shin (1985) suggested the opposite, based on an analysis of electricity utility data.

3.2. ***Efficiency metrics***

Most water utilities aim to be efficient. In this paper, we focus on economic efficiency where resources are allocated in a way that maximizes social welfare. Researchers will estimate the economic efficiency of potential changes in water tariffs by calculating the welfare gains (losses) associated with that change. Yet the rate structure, by itself, does not provide information about water demand or utility costs, making it impossible to draw conclusions about the efficiency of a utility based on rate decisions alone. Nonetheless, in a perfectly efficient rate structure, marginal price would equal marginal cost, making marginal price a highly scrutinized metric by practitioners and researchers.

3.2.1. *Marginal price*

The marginal price is what a consumer pays for one additional unit of a good. In a flat rate, the marginal price is 0, since additional consumption comes at no cost. When rate structures are volumetric, the marginal price will depend on consumption levels.

Economic theory suggests that utilities adopt marginal cost pricing, in which prices (charges) are set to the utilities' long-term marginal cost. Critically, the marginal price confronted by consumers in the rate structure is not necessarily reflective of the marginal cost of the utility, so both metrics should not be confused. Only in a perfectly optimal system, would the long-run marginal cost of a utility be equal to the marginal price paid by water users.

The marginal price is used to model water demand but it is not clear if users accurately perceive the marginal price under increasing or decreasing block rates (Gibbs 1978; Arbués *et al.* 2003; Taylor *et al.* 2004; Reynaud *et al.* 2005; House-Peters and Chang 2011; Nataraj and Hanemann 2011). It has also been argued that setting high marginal prices at higher levels of consumption can send signals to encourage resource conservation (Berahzer *et al.* 2011). Using data from municipalities in Wisconsin (United States), Fenrick and Getachew (2012) showed that price elasticity increases with price, providing suggestive evidence that marginal price can be more influential at higher levels of consumption.

3.3. *Cost recovery metrics*

Utilities will set rate structures to cover the operational and capital costs associated with water extraction, treatment, transport, system maintenance and wastewater treatment. Fixed fees are an important strategy to maintain revenue stability, and ensure that operation costs are covered. In some contexts, especially in developed countries, there are regulatory mandates that require cost recovery. The presence of environmental taxes and sewage charges may be reflective of this regulatory environment and suggest that a utility is aiming to recover its long-term capital costs or the external environmental costs of operation. Thus, while the rate structure alone cannot demonstrate cost-recovery, it may provide clues about how a utility is performing in this regard.

3.3.1. *Fixed charge*

The fixed charge of the rate structure is the sum of all minimum charges, base charges or fixed fees, and usually these charges are intended to recover capital and operational costs (Barberán and Arbués 2009). Thus this metric may be a proxy for how much the utility is seeking to recover capital costs, internalize environmental externalities, or maintain revenue stability.

It should be noted that a volumetric charge with a *minimum charge* sends different signals to consumers than a volumetric charge with a *base charge*. In the first, after the minimum charge has been reached, the rate turns into a purely volumetric charge, while in the second, the base charge always has an influence on the rate.

3.3.2. *Percent fixed charge*

The fixed charge of a water bill may also be expressed as a percent of the water bill, and this percent will shrink with increased consumption. An advantage of using *percent fixed charge* rather than the total is that it illustrates how aggressively the utility may be aiming to recover costs and maintain revenue stability. Moreover, this metric may also help assess the rate structure in terms of conservation and equity goals. Large fixed charges tend to discourage conservation since it dampens incentives in the volumetric component. Similarly, large fixed charges may hurt equity goals since households with lower incomes, or smaller households, which usually consume less water, will end up paying relatively more.

3.4. *Equity metrics*

Utilities often aim to create rate structures that are fair and affordable. Few would dispute that a water rate should charge a fair price and allow people of all income-levels to access water. In this sense, equity has two interpretations: *affordability*, everyone pays only what they are able to pay; and *fairness*, each user pays in proportion to the benefit they receive (Bakker 2001; Barberán and Arbués 2009; García-Valiñas *et al.* 2010). Acknowledging this distinction, we discuss metrics that concern affordability and fairness separately.

3.4.1. *Affordability metrics*

3.4.1.1. Lifeline volume

The lifeline volume is the amount of water available in the first block of a volumetric rate structure. The first block is referred to as the "lifeline" when it is the expected minimum amount to meet a household's basic needs. Water utilities in developing countries often use lifeline volumes in order to ensure access (Dinar 2000). A frequently cited advantage of increasing block rate structures is that it offers water managers the ability to establish lifeline consumption volumes to provide a low cost or free water supply to low income households (Agthe and Billings 1987; Howe 2005). However, lifeline volumes also create distortions in the water market and it has been argued that a direct income subsidy would be preferable (Barberán and Arbués 2009). On the other hand, subsidizing the lifeline volume in the rate structure provides immediate benefit to low volume users (García-Valiñas *et al.* 2010).

3.4.1.2. Lifeline charge

One may also compare how much the utility charges for the lifeline volume, which is essentially the charge at the end of the first block in an increasing block rate.

In many instances, utilities offer a free allowance, making the lifeline charge zero. Since the purpose of this metric is to measure affordability, one should always compare the lifeline charge in absolute terms rather than a charge per cubic meter.

3.4.1.3. Charge to meet basic needs

Analysts may also be interested in estimating the financial burden imposed on households for meeting basic water needs. This comparison requires one to determine a minimum volume requirement. While this minimum volume requirement will depend on the community and the household, a common reference level is 135 liters per capita per day (Chenoweth 2008). The charge to meet basic needs has two advantages, it can be calculated for all pricing arrangements since it does not need a first block, and it allows for easy comparison across utilities.

3.4.1.4. Percent of household income spent on water

Affordability may also be measured by estimating the percent of income spent on water. Yet the best way to calculate this remains unclear. Most analysts divide the charge at the benchmark level (usually 15, 20 or 25 m^3 per month) by the median or average income (Berahzer *et al.* 2011). However, this is somewhat problematic since the average water charge tends to be skewed upwards by high water users, making it less relevant to low end users (García-Valiñas *et al.* 2010). Similarly, the median income is unlikely to be representative of lower income users who have affordability challenges (Zetland and Gasson 2013). To address these biases, one might calculate this affordability metric specifically with lower income users in mind, and use the water volume to meet basic needs, and an income level below the median. In any case, depending on the objectives of the analysis, the water consumption level and income parameter should be chosen accordingly.

3.4.2. *Fairness metrics*

3.4.2.1. Charge per person

The *charge per person* corresponds to the total bill of the household divided by the numbers of individuals living in the dwelling. This metrics may help utility managers assess if their rate structure is generating an unfair burden per person, especially for larger households who may use more water in total, but may use less water per person. Authors concerned about unfair rate structures have advocated for charging water at a per capita level (Dahan and Nisan 2007; Barberán and Arbués 2009; Baerenklau *et al.* 2014). The use of *water budgets*, in which water rates depend on household characteristics, may address this fairness issue

(Baerenklau *et al.* 2014). Note that this metric cannot be calculated from the water rate only, and must be combined with household-level data.

3.5. *Water conservation metrics*

Finally, utilities often want to use the rate structure to send price signals that encourage water conservation and wise water use. The strength of the price signal sent to consumers depends on the rate structure chosen. This is especially important in water scare regions, where the rate structure may be designed to incentivize water conservation.

3.5.1. *Rate steepness*

Although not widely used, *rate steepness* measures how quickly an increase in consumption will translate into a percent increase in the total water charge. More formally, *rate steepness* is the percent increase (decrease) of the charge relative to a reference level, for example, the previous charge. *Rate steepness* provides an intuitive measure of the price signal sent to consumers, and is likely to influence water use decisions consumers made. This metric has been suggested in (Agthe and Billings 1987; Liebman and Zeckhauser 2004; Silva Pinto and Cunha Marques 2016) but remains rarely used. This metric has the disadvantage of being a relative measure that varies over consumption making it difficult to provide a single summary statistic for the entire rate structure.

3.5.2. *Billing frequency*

Utilities may bill customers monthly, bi-monthly, quarterly or annually. One might expect that more frequent billing frequency would increase the salience of water use and therefore lead to water conservation, therefore the importance of this metric. However, no conclusive results have been found on this question (Arbués *et al.* 2003; Howe 2005; Fenrick and Getachew 2012). Some have suggested that less frequent bills produce a “shock effect” on consumers with infrequent but large bills (Arbués *et al.* 2003), a recent study provided evidence to support this hypothesis (Wichman 2015).

3.5.3. *Charge at the last block*

The charge at the last or most expensive block may suggest how much a utility is willing to punish the highest water users since, usually, the last block is a penalty block set to encourage water conservation (Baerenklau *et al.* 2014). The last block will not necessarily be the most expensive block if the utility uses decreasing block rates.

3.5.4. *Volume at the most expensive block*

The consumption volume at which a consumer enters the most expensive block may also be insightful, especially if this volume is unusually low or high. As above, how quickly a consumer enters this expensive block will illustrate how much a utility aims to promote water conservation. This metric could be interpreted jointly with the *Charge at the last block* since one reveals how much water a utility considers to be excessive; and the other reveals the size of the penalty they are willing to impose for this excess consumption.

3.5.5. *Number of blocks*

The number of blocks provides a rough measure of how much the utility is interested in raising charges to the higher water users. More blocks also suggest that the utility has reason to distinguish various types of water users.

4. Comparing Rate Structures in British Columbia, Canada

In this section we illustrate how one might use the metrics presented to analyze five water utilities in British Columbia, Canada (Table 3). Local governments in Canada have complete authority over water utility rates, creating a diverse mosaic of rate structures across the country. Water charges in Canada are generally one-quarter of European rates, and three-quarters of American rates (Vander Ploeg 2011). Economists have been critical of rate structures in Canada for being too low, inefficient and responsible for encouraging overconsumption (Renzetti 2009).

The City of Vancouver is the most dense and populous of the selected cities, and is seen as a leader in environmental issues, as exemplified by its goal to become the world's "Greenest City" (Scerri and Holden 2013). West Vancouver is a lower density city, neighbouring Vancouver with a much higher median household income. In 2005, West Vancouver chose to develop a universal metering program that resulted in moving from a flat fee to an increasing block rate. Both Vancouver and West Vancouver purchase their water from Metro Vancouver, a bulk water provider, making their rate decisions dependent on the rates they obtain from Metro Vancouver. Nanaimo is located on Vancouver Island, and has confronted periods of water scarcity, most recently during the drought of 2015 (Honey-Rosés *et al.* 2016a). Similarly Abbotsford, located in an agricultural region, has a constrained water supply, and the city has invested considerable resources in water conservation programs. Currently Abbotsford is moving toward an advanced metering infrastructure. Lastly, Chilliwack is located in the agricultural Fraser Valley and they rely on groundwater for their supply. The abundant groundwater provides Chilliwack with low treatment costs and reduced pressure to build water

Table 3. A Comparison of the Rate Structures in the Five Selected Municipalities. All Volumes and Charges are Monthly. The Average Charge, Marginal Charge and Percent Fixed Charge are calculated at the Canadian Standard of 25 m^3/month. The Volume for Basic Needs is 12.2 m^3/household/month and the Relevant Income Level at the Canadian Low-Income Cut Off (LICO)

	Abbotsford	Chilliwack	Nanaimo	Vancouver	West Vancouver	Observations
Rate Type	Constant Unit Charge	Constant Unit Charge + Minimum Charge	Increasing Block Rate + Base Charge	Flat	Increasing Block Rate + Base Charge	
Charge at 25 m^3 ($)	29	11	29	47	47	We observe the exact same charge in Abbotsford and Chilliwack ($29); Vancouver and West Vancouver ($47) at this volume, suggesting that there is a “looking over the shoulder effect” among similar or neighbouring municipalities.
Charge at average consumption ($)	18	10	NA	47	58	In practice, the charge at average consumption shows that the charge at 25 m^3 overestimates the charge faced by most users in Abbotsford and Chilliwack but underestimates the charge in West Vancouver.
Average charge per unit ($/$m^3$)	1.2	0.4	1.1	1.9	1.9	IRB and Flat rates can have the same average charge but vastly different incentives for users.

Table 3. (*Continued*)

	Abbotsford	Chilliwack	Nanaimo	Vancouver	West Vancouver	Observations
Rate Type	Constant Unit Charge	Constant Unit Charge + Minimum Charge	Increasing Block Rate + Base Charge	Flat	Increasing Block Rate + Base Charge	
Marginal charge ($\$/m^3$)	1.2	0.4	1.3	0	1.4	We observe aggressive marginal charges in Abbotsford, Nanaimo and West Vancouver. However West Vancouver's large fixed fees dilutes the impact and relevance of this high marginal charge.
Fixed component ($)	0	7.2	1.4	47	19	The high fixed component in West Vancouver and Vancouver provides revenue stability. Abbotsford is entirely reliant on consumption for revenue.
Percent fixed charge	0%	0%	5%	100%	40%	West Vancouver has a large percent fixed charge, which supports cost recovery but reduces the strength of price signal for water conservation.
Lifeline volume (m^3)	—	—	5	—	20	Only Nanaimo provides a detailed rate structure for low volume users and small families or individuals.
Lifeline charge ($)	—	—	21.5	—	95.2	As a high-income community, the rate structure in West Vancouver is not designed for low-income residents.

Table 3. (*Continued*)

	Abbotsford	Chilliwack	Nanaimo	Vancouver	West Vancouver	Observations
Rate Type	Constant Unit Charge	Constant Unit Charge + Minimum Charge	Increasing Block Rate + Base Charge	Flat	Increasing Block Rate + Base Charge	
Charge to meet basic needs ($)	14.0	7.2	11.6	47.3	31.5	The flat fee in Vancouver makes it very expensive at low consumption levels and less affordable.
Percent of household income spent of water	0.7%	0.3%	0.5%	1.9%	1.2%	The rates are affordable in Chilliwack, Abbotsford and Nanaimo. They are more burdensome for low-income residents in Vancouver and West Vancouver.
Billing frequency (bills/year)	6	4	3	1	4	The flat fee has the advantage of administrative simplicity. Chilliwack, despite low rates, bills quarterly.
Charge at last block ($)	—	—	201	—	303	The total charge in the last block are considerably high in both IBRs, but higher in West Vancouver.
Volume at most expensive block (m^3)	—	—	37	—	60	Nanaimo introduces the last block much earlier than West Vancouver.
Number of blocks	0	0	6	0	3	The detailed IBR in Nanaimo suggests interest in water conservation, efficiency and affordability.

reserves or large infrastructure in the near future. Both Chilliwack and Abbotsford use a constant unit charge, while Nanaimo and West Vancouver have adopted increasing block rates. Vancouver is the only city in our selected group that uses a flat rate, although this is the dominant rate structure in British Columbia, where metering coverage rates are generally low (Honey-Rosés *et al.* 2016b).

4.1. *Descriptive metrics*

When comparing a small number of rate structures, analysts may show the full functional form of the total or marginal charge (Figure 1). The graphical depiction of the marginal charge is more common, probably because the bylaws are written in terms of marginal charges and because the step function of an increasing block rate is more clearly illustrated with marginal charges (Figure 1(b)). However for the public, the depiction of the total charge may be more informative (Figure 1(a)).

For our analytical purposes, graphing key metrics on the functional form allows us to appreciate the error or bias associated with a particular metric. The most widely used metric to describe a rate structure is the *charge at a consumption volume*, however if consumption is highly variable across municipalities, it might not accurately compare the prices confronted by most users in practice. The federal government of Canada compares municipal water rates with the*charge at a consumption volume* of 25 m^3/month (Environment Canada 2011). We can visually assess the performance of *the charge at a consumption volume* compared to estimates derived with the *charge at average consumption*, as reported by each municipality (Figure 1(a)). The vertical line at 25 m^3/month identifies the charge that would have been estimated using the *charge at a consumption volume*, while the dots identify the observed *charge at average consumption*. Only in flat fee structures are the two charges identical. We do not have consumption data for Nanaimo, but in the remaining three municipalities, these two estimates differed by between 9% and 38%, illustrating significant divergence. In short, two metrics that sound very similar can in fact produce very different estimates. When comparing the two, we suggest that the *charge at average consumption* may be a better approximation of what most users are paying in practice, and that this metric is preferable over the *charge at a consumption volume*, if average consumption data is available.

Visualizing the functional form in conjunction with reported water use data also reveals other insights. It may be surprising to observe that Vancouver, despite its adoption of a flat fee, consumes less water than municipalities with both higher and lower charges (Figure 1(a)). Also, when looking at the total charges we observe the convergence of two pairs, West Vancouver & Vancouver, and Nanaimo &

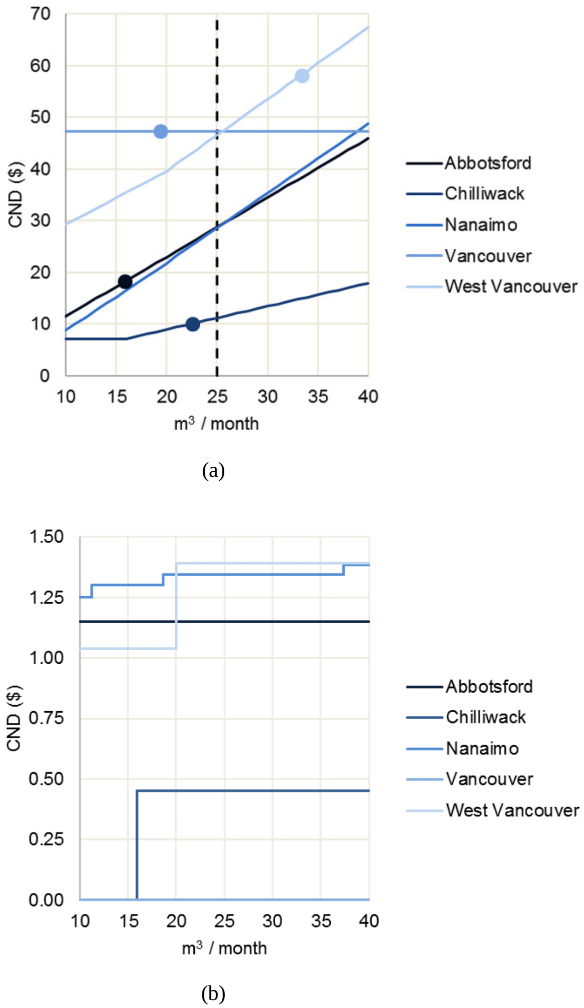

Figure 1. (a) The Functional Form of the Total Water Charges and (b) Marginal Water Charges for the Selected Municipalities. Volumes and Charges Have Been Converted to Monthly Equivalents for Comparison. The Dots in (a) Locate the Charge Based on Reported Average Consumption Volumes

Abbottsford, at precisely the charge at $25\,\text{m}^3$/month (Figure 1(a)). We speculate that this is not a coincidence, but rather a product of the Canadian federal standard at $25\,\text{m}^3$/month, in which municipal governments aim to align their rates with other cities. This provides suggestive evidence of the "looking over the shoulder effect", in which municipalities may be aiming to converge their rate structure at a consumption level where they will be scrutinized ($25\,\text{m}^3$/month).

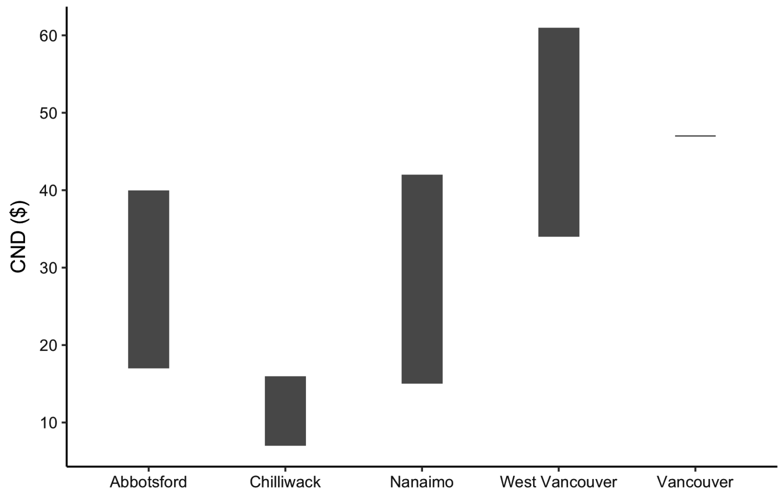

Figure 2. The Box-Plot Shows Total Water Charges for Monthly Household Consumption between 15 m^3 and 35 m^3, Centered Around 25 m^3. Water Rates are Highly Variable Across and Within Municipalities

One drawback associated with presenting the full functional form of a rate structure is that it is more difficult to appreciate the variability. To highlight the variability across and within municipal rate structures, we used a bar chart that is centered around a standard consumption volume (Figure 2). Note that the rate structures in Figure 2 are the same as presented in Figure 1 and yet the bar chart makes it easier to observe the variability.

4.2. *Efficiency*

Analysts will often examine the average and marginal price (charge) of a rate structure. By plotting these values together, one can easily appreciate how municipalities compare according to these metrics (Figure 3). Municipalities placed on the 1:1 line have an average and marginal charge that are equal (MC = AC), as you would expect with a constant unit charge without a fixed charge (Abbotsford and Chilliwack). For any community below the line, the marginal price is less than the average charge per unit (West Vancouver, IBR). The extreme case of this is a flat charge, in which the marginal charge is zero (Vancouver). Finally, for any community above the line, the marginal price is greater than the average charge, meaning the community aggressively increase the marginal price (Nanaimo, IBR). Note that we see IBR rate structures above *and* below the MC = AC line, depending on the size of any fixed charge and how aggressive they increase their marginal rates.

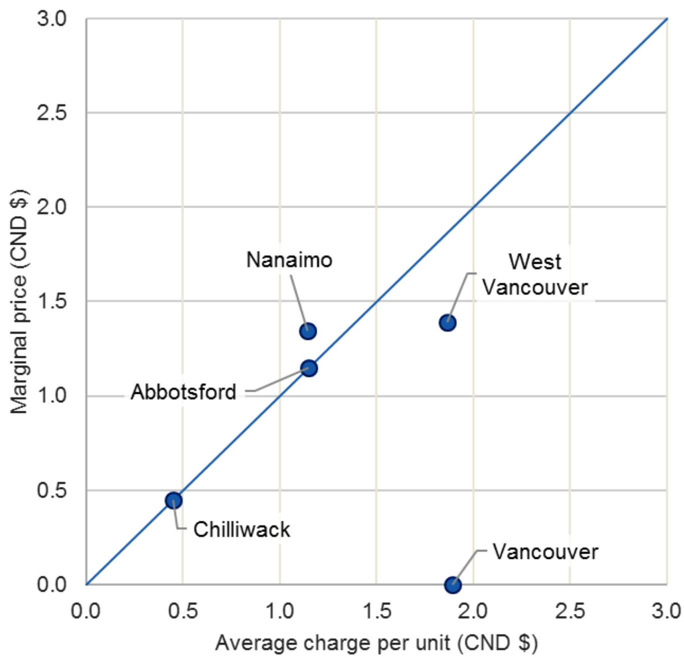

Figure 3. Average Charge per Unit Versus Marginal Price per Unit at Reference Level of a Monthly Consumption of 25 m^3

4.3. *Cost recovery*

The fixed charge of a utility bill is critical for cost recovery but also adds distortions to the rate structure. Rate structures that look similar in many respects may send vastly different signals to consumers depending on the presence, absence or size of fixed charges and fees. For example, both Nanaimo and West Vancouver have IBR rate structures, yet West Vancouver has larger fixed charge that comprises around 40% of the bill for a wide range of consumption volumes (Figure 4). When fixed charges are very large, and the volumetric charge only makes a small contribution to the total charge, the volumetric rate may resemble a flat rate.

4.4. *Equity*

To analyze affordability, we examined the monthly *charge to meet basic needs*, in which we estimate the basic needs of a family of three to be 135 liters per capita per day (Chenoweth 2008) or 12.2 m^3/month. In the municipalities studied, the *charge to meet basic needs* varies from \$7/month in Chilliwack to \$47/month in Vancouver (Figure 5), almost 7 times more expensive. This metric illustrates how flat rates are expensive at low consumption levels.

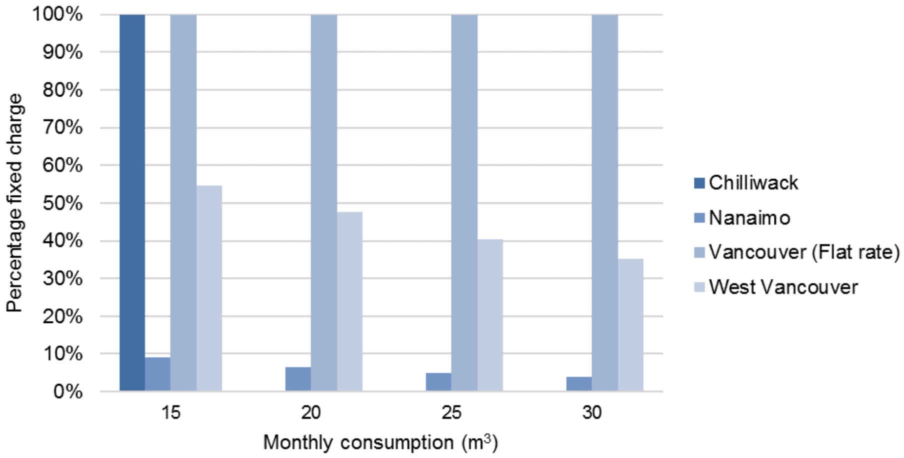

Figure 4. A Comparison of the Proportion (%) of a User's Water Bill Devoted to the Fixed Charge of their Total Bill. While Nanaimo and West Vancouver both have IBR Rate Structures, West Vancouver has Much Larger Fixed Charges across Consumption Levels. Chilliwack has a Minimum Charge of 15 m^3, Making the Fixed Charge 100% below this Volume but 0% after

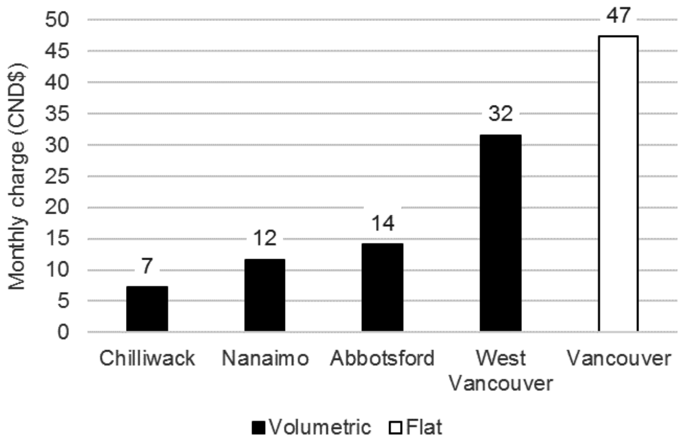

Figure 5. A Comparison of a Household's Monthly Water Charge for a Consumption Level That Meets the Monthly Basic Need of 12.2 M^3/month

Affordability may also be expressed as *percent of household income* spent on water. We use two consumption levels for this analysis: a lifeline volume of 12.2 m^3/month for a household of 3 and the Canadian standard of 25 m^3/month (Figure 6). With regards to income, we also use two levels: the median household income of 2010 in 2015 dollars and the 2015 Canadian Low-Income Cut Off

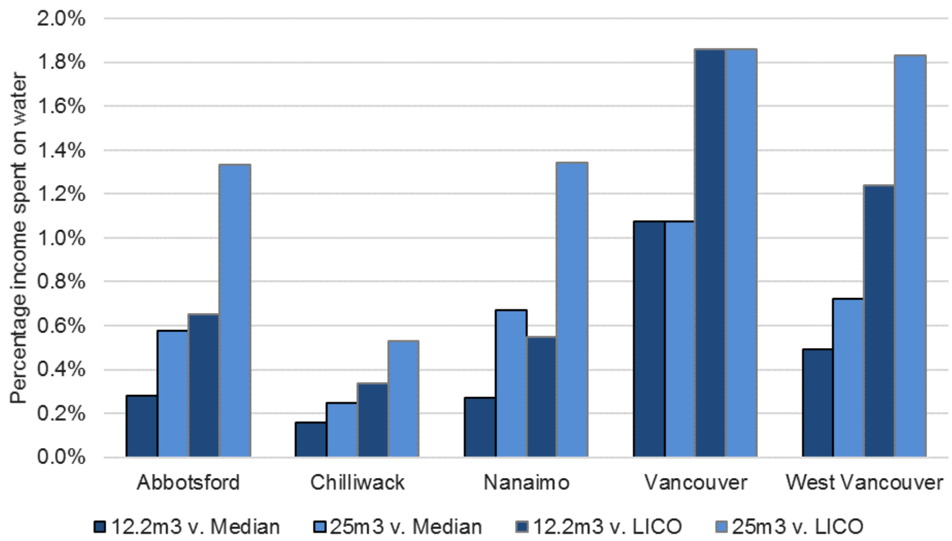

Figure 6. Percent of Household Income Spent on Water for Different Consumption and Income Parameters

(LICO), as the minimum annual income to meet basic needs. LICO is calculated according to household size and city population, for example, for a household of three in a major city, the 2015 LICO is CND$ 30,895 (Statistics Canada 2012). By using these different parameters, we illustrate that while each of the metrics consistently show where water is more affordable, the definition of which consumption and income levels are used could lead to important differences in the calculations.

Finally, an increasing block rate may support low-income households by subsidizing the first block with a lifeline volume at an inexpensive charge. Considering that our subset has only two IBR municipalities, we used all the available data set to test this assumption. We find that from 7 municipalities in British Columbia with IBR, only three have small first blocks ($< 5\,\text{m}^3$/month) while three municipalities have large first blocks ($> 20\,\text{m}^3$/month) (Figure 7). In the case of West Vancouver, the first block is both large and expensive. When utility managers design an increasing block rate with a very generous first block, these rate structures begin to resemble a flat rate, especially if, in practice, few consumers enter the second block.

4.5. *Water conservation*

To assess how a municipality penalizes high volume water users, we focus on communities with an IBR structure. For these communities we plot the *total charge at the last block* and *consumption level of the last block*. As before, our

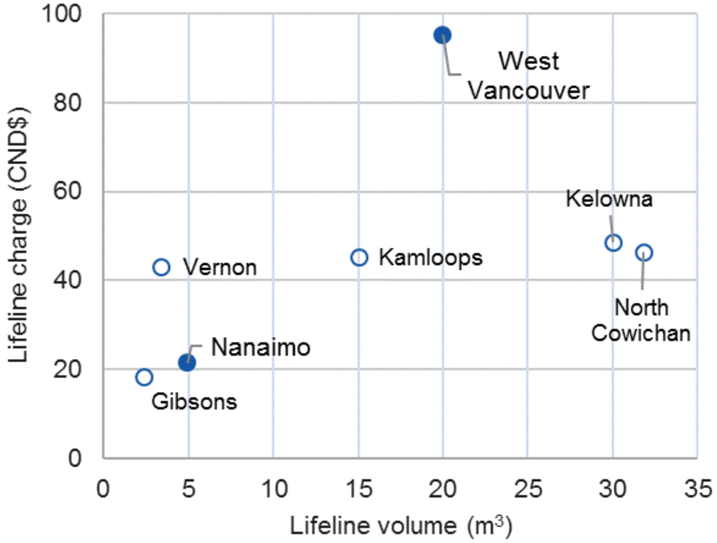

Figure 7. A Comparison of Lifeline Volumes and Lifeline Charges for the Seven Municipalities in British Columbia that Reported Using an Increasing Block Rate Structure in the BC Municipal Water Survey. Only Three Municipalities have Small First Blocks ($<5\,m^3$/month) while Three Municipalities have Very Large First Blocks ($>20\,m^3$/month). The Filled Circles Identify Municipalities Studied in Greater Detail

figure includes all municipalities in the BC Municipal Water Survey with an IRB (Figure 8).

While larger blocks tend to be more expensive, the largest last block (North Cowichan) is five times the smallest (Vernon) and yet their total charge at that consumption volume are both around $200 CND. Most municipalities (4) begin their last block at or below 60 m^3 per month, while the two outliers — Kelowna and North Cowichan — begin the last block at double that amount. In terms of charges, five municipalities charge less than CND$ 300 with the remaining one, charging around CND$500. This analysis suggests that the city of Gibsons has most aggressively aimed to penalize high water users. In contrast, while Kelowna and North Cowichan have an IRB, their existing rates send much weaker signals to promote conservation. It remains possible that contextual factors, such as lot size or agricultural uses may explain the high consumption volume and low total charge in the last block for Kelowna and North Cowichan.

4.6. *Synthesis of case comparison*

In our selected municipalities in British Columbia, our metrics help clarify the context and priorities of water managers (Table 3). Interestingly, despite having

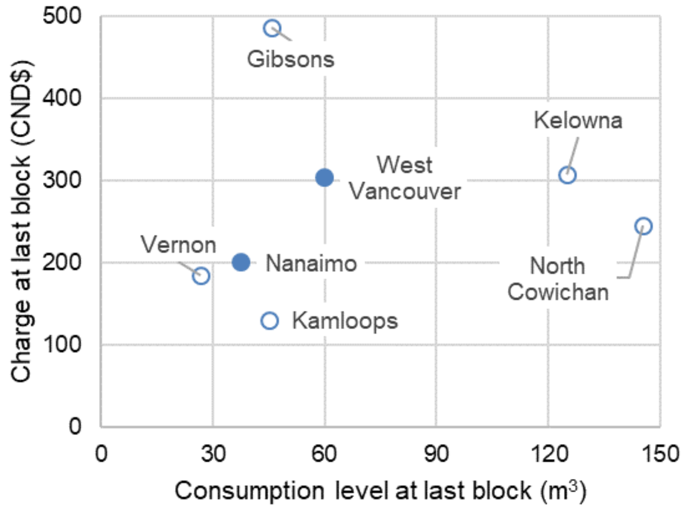

Figure 8. Comparison of Charges at the Last Block and Consumption Levels of these Last Blocks for Municipalities with IBR. Communities in the Upper Left are Most Aggressive at Penalizing High Volume Users because this Block is Smaller in Volume and More Expensive. The Filled Circles Correspond to Municipality in our Original Selection of Five

very different rate structures, two pairs of municipalities converge at the Canadian standard of 25 m^3/month (Figure 1, Table 3) suggesting that managers are probably cognizant of the metrics used to compare themselves to others, and that indeed, there is a "looking over the shoulder effect". But while charges converge for this particular metric, we see important differences in other dimensions and at other consumption volumes. Many of these differences may be explained by the local context, but certainly also by the priorities or aims of the designers of the rates themselves.

For example, we observe that choices pertaining to the fixed charge are critical. While fixed charges can assist managers with revenue stability and cost recovery, there is a trade-off with goals pertaining to equity, affordability and water conservation. In West Vancouver we observe that large fixed charges can mitigate the incentives introduced by volumetric charges, and very large fixed charges could create an incentive structure that begins to resemble a flat rate.

The size of the first block of a rate structure is also illustrative. One might assume that an Increasing Block Rate is designed to prioritize water conservation and efficiency, however we observe that very large blocks, in which few households move between blocks, in practice will make an IBR resembles a constant unit charge for a wide range of consumption values.

We observed that the rate structure in Nanaimo sent the strongest price signals to consumers across consumption volumes. This aggressive increase in price over consumption values is reflected in the high marginal charge. Nanaimo is also the only rate structure with a marginal charge higher than its average charge, again showing that it aims to incentivise efficiency and water conservation (Figure 3).

The metrics also illustrate the strengths and weaknesses of particular rate structures. For example, the flat rate of Vancouver is administratively simple and ensures revenue stability but performs poorly in terms of affordability — making water very expensive for low income and low consuming households — and provides no incentive for water conservation. These weaknesses of the flat rate are certainly well known, however the quantification and comparison with the metrics allows one to appreciate these differences on more specific terms.

While some trade-offs are inevitable, we observe that Nanaimo is able to maintain affordability for low income and low consuming households, but also send strong price signals to high-end consuming households. Nanaimo performs well on affordability metrics (Figures 6 and 7) but also punishes high water users. Similarly, Chilliwack has designed a rate with highly affordable water for all users — perhaps because of its contextual advantage — but the constant unit charge also sends strong price signals by making the total charge fully dependant on consumption (Figure 4). Note that Chilliwack's minimum charge functions very well to address both affordability and cost-recovery while not affecting conservation signals for high-level consumption users.

In contrast, West Vancouver and Abbotsford charge high rates for high water users, but are less affordable overall. The former is because of the expensive first block and the latter because of its high marginal charge. Considering how important fixed charges are for West Vancouver, we hypothesise that the rate design aimed to prioritize cost-recovery, a focus that seems absent in Abbotsford where every charge is consumption-dependant.

5. Conclusion

We have reviewed the metrics, methods and approaches used to compare the rate structures of water utilities. These metrics help water managers assess potential cost recovery, revenue stability, fairness, affordability and the strength of the price signal sent to consumers to encourage water conservation. Our review of the literature finds that these metrics may differ in how they are defined and interpreted. We find that some metrics commonly used may be misleading because of different ways in which they are calculated (average water charge; percent household income spent on water) or because of the underlying variability in consumption across and within jurisdiction (charge at a consumption volume).

More importantly, perhaps, we hope to illustrate how these metrics may be used to glean insight when making cross utility comparisons. While recognizing that differences in context may largely explain different pricing structures, we argue that comparing rate structures may highlight how utilities make decisions or trade-offs for competing priorities. For example, the use of these metrics may help water managers quantify the weaknesses of particular rate structure types, such as the equity challenges of flat rates, or illustrate that IBR structures may not be living up to their promise of efficiency and affordability.

These metrics and methods are most useful to analysts interested in learning how a particular utility's rate structure compares to others across a range of dimensions. Clearly, this is no substitute for a detailed analysis of billing information, consumer demand and utility costs. However few utilities are likely to obtain this detailed information of their neighbours, making the approach presented in this paper a valuable starting point for comparison.

Our examples showed that our approach presents complex information in a simple, standardized and replicable way, and relates it back to specific goals. This approach may be useful even in more regulated markets where there is a central entity that has all the detailed rate and billing information, the resources and time needed to interpret it, as well as the complexity to communicate it to policy makers and the public. Further, because contextual information for each rate design is important, the comparison of rates based on these metrics may help inform observers about what contextual information to look for. Indeed, by having the full range of available metrics, one can see on which term rates differ between jurisdictions. Lastly, we hope that our review of the range of metrics available may push future analysts to look beyond the most frequently used metric — *charge at a specific volume* — and consider alternative measures that may be more relevant to their particular circumstances.

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References

Agthe, DE and RB Billings (1987). Equity, Price Elasticity, and Household Income Under Increasing Block Rates for Water. *J Econ*, 46:273–286. doi: 10.1111/j.1536-7150.1987.tb01966.x.

Arbués, F, MA García-Valiñas and R Martínez-Espiñeira (2003). Estimation of residential water demand: A state-of-the-art review. *Journal of Socio-Economics*, 32, 81–102, doi: 10.1016/S1053-5357(03)00005-2.

Baerenklau, KA, KA Schwabe and A Dinar (2014). The residential water demand effect of increasing block rate water budgets. *Land Economics*, 90, 683–699.

Bakker, K (2001). Paying for water: Water pricing and equity in England and Wales. *Transactions of the Institute of British Geographers*, 26, 143–164, doi: 10.1111/1475-5661.00012.

Barberán, R and F Arbués (2009). Equity in Domestic Water Rates Design. *Water Resour Manag*, 23:2101–2118, doi: 10.1007/s11269-008-9372-3.

Berahzer, SI, S Eskaf and J Hughes (2011). Benchmarking Utilities' Rates and Finances for Decision and Policy Makers.

Berg, S (2007). Conflict resolution: Benchmarking water utility perfomance. *Public Administration & Development*, 1–11, doi: 10.1002/pad.437.

Berg, S (2010). *Water Utility Benchmarking: Measurement, Methodologies, and Performance Incentives*. London: IWA Publishing.

Berg, S and R Marques (2011). Quantitative studies of water and sanitation utilities: A benchmarking literature survey. *Water Policy*, 13, 591–606, doi: 10.2166/wp. 2011.041.

Chenoweth, J (2008). Minimum water requirement for social and economic development. *Desalination*, 229, 245–256, doi: 10.1016/j.desal.2007.09.011.

Chica-Olmo, J, F González-Gómez and J Guardiola (2012). Do neighbouring municipalities matter in water pricing? *Urban Water Journal*, 9006, 1–9, doi: 10.1080/1573062X.2012.690436.

Dahan, M and U Nisan (2007). Unintended consequences of increasing block tariffs pricing policy in urban water. *Water Resources Research*, 43, 1–10, doi: 10.1029/2005WR004493.

Dalhuisen, JM, RJGM Florax, HLF de Groot and P Nijkamp (2003). Price and income elasticities of residential water demand: A meta-analysis. *Land Economics*, 79, 292–308.

Dinar, A (Ed.) (2000). *The Political Economy of Water Pricing Reforms*. New York: Oxford University Press.

Environment Canada (2011). 2011 Municipal Water Pricing Report: Municipal Water Pricing 2009 Statistics. Ottawa.

Feldman, S and A Gonen (1975). Spatiotemporal pricing of some urban public-services — urban ecology, equity, and efficiency. *Environment and Planning A*, 7, 315–323, doi: 10.1068/A070315.

Fenrick, SA and L Getachew (2012). Estimation of the effects of price and billing frequency on household water demand using a panel of Wisconsin municipalities. *Applied Economics Letters*, 19, 1373–1380, doi: 10.1080/13504851.2011. 629977.

García-Valiñas, M Á de los, R Martínez-Espiñeira and F González-Gómez (2010). Measuring water affordability: A proposal for urban centres in developed countries. *International Journal of Water Resources Development*, 26, 441–458, doi: 10.1080/07900627.2010.491971.

Gibbs, KC (1978). Price variable in residential water demand models. *Water Resources Research*, 14, 15–18, doi: 10.1029/WR014i001p00015.

Gómez-Ibañez, J (2003). *Regulating Infrastructure: Monopoly, Contracts and Discretion*. Cambridge: Harvard University Press.

Honey-Rosés, J *et al.* (2016a). Drought Preparedness in BC: Workshop Summary. Water Planning Lab. School of Community and Regional Planning. University of British Columbia.

Honey-Rosés, J, D Gill and C Pareja (2016b). BC Municipal Water Survey 2016. Water Planning Lab. School of Community and Regional Planning. University of British Columbia, http://hdl.handle.net/2429/57077.

Hoque, SF and D Wichelns (2013). State-of-the-art review: Designing urban water tariffs to recover costs and promote wise use. *International Journal of Water Resources Development*, 29, 472–491, doi: 10.1080/07900627.2013.828255.

House-Peters, LA and H Chang (2011). Urban water demand modeling: Review of concepts, methods, and organizing principles. *Water Resources Research,* doi: 10.1029/2010WR009624.

Howe, CW (2005). The functions, impacts and effectiveness of water pricing: Evidence from the United States and Canada. *International Journal of Water Resources Development,* 21, 43–53, doi: 10.1080/0790062042000316811.

Kayaga, S and IK Smout (2014). Tariff structures and incentives for water demand management. *Proceedings of the Institution of Civil Engineers — Water Management,* 167, 448–456, doi: 10.1680/wama.12.00120.

Liebman, JB and RJ Zeckhauser (2004). Schmeduling.

Martínez-Espiñeira, R, M Á de los García-Valiñas and F González-Gómez (2012). Is the pricing of urban water services justifiably perceived as unequal among spanish cities? *International Journal of Water Resources Development,* 28, 107–121, doi: 10.1080/07900627.2012.642231.

Nafi, A, J Tcheng and P Beau (2015). Comprehensive methodology for overall performance assessment of water utilities. *Water Resource Management*, 29, 5429–5450, doi: 10.1007/s11269-015-1127-3.

Nataraj, S and WM Hanemann (2011). Does marginal price matter? A regression discontinuity approach to estimating water demand. *Journal of Environmental Economics and Management*, 61, 198–212, doi: 10.1016/j.jeem.2010.06.003.

OECD (2002). Social Issues in the Provision and Pricing of Water Services.

OECD (2009). Managing Water for All: An OECD Perspective on Pricing and Financing. Organisation ofr Economic Co-operation and Development, Paris.

Olmstead, SM and RN Stavins (2009). Comparing price and nonprice approaches to urban water conservation. *Water Resource Research*, 45, 1–10, doi: 10.1029/2008 WR007227.

Renzetti, S (1999). Municipal water supply and sewage treatment: Costs, prices, and distortions. *Canadian Journal of Economics*, 32, 688–704.

Renzetti, S (2009). *Wave of the Future: The Case for Smarter Water Policy*. Toronto, Canada: C.D. Howe Institute.

Reynaud, A, S Renzetti and M Villeneuve (2005). Residential water demand with endogenous pricing: The Canadian case. *Water Resources Research*, 41, 1–11, doi: 10.1029/2005WR004195.

Rogers, P, R De Silva and R Bhatia (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy*, 4, 1–17, doi: 10.1016/S1366-7017(02)00004-1.

Scerri, A and M Holden (2013). Ecological modernization or sustainable development? Vancouver's greenest city action plan: The city as "manager" of ecological restructuring. *Journal of Environmental Policy & Planning*, 16, 261–279, doi: 10.1080/1523908X.2013.836962.

Schoengold, K and D Zilberman (2014). The economics of tiered pricing and cost functions: Are equity, cost recovery, and economic efficiency compatible goals? *Water Resources and Economics*, 7, 1–18, doi: 10.1016/j.wre.2014.07.002.

Shin, J-S (1985). Perception of price when price information is costly: Evidence from residential electricity demand. *The Review of Economics and Statistics*, 591–598.

Sibly, H and R Tooth (2013). The consequences of using increasing block tariffs to price urban water. *Australian Journal of Agricultural and Resource Economics*, 223–243, doi: 10.1111/1467-8489.12032.

Silva Pinto, F and R Cunha Marques (2016). Tariff suitability framework for water supply services: Establishing a regulatory tool linking multiple stakeholders' objectives. *Water Resource Management*, 1–17, doi: 10.1007/s11269-016-1268-z.

Statistics Canada (2012). Low Income Lines, 2010 to 2011. Minister of Industry — Canada, Ottawa.

Taylor, RG, JR McKean and RA Young (2004). Alternate price specifications for estimating residential water demand with fixed fees. *Land Economics*, 80, 463–475, doi: 10.2307/3654732.

Thorsten, RE, S Eskaf and J Hughes (2009). Cost plus: Estimating real determinants of water and sewer bills. *Public Work Management Policy*, 13, 224–238, doi: 10.1177/1087724X08324302.

Vander Ploeg, CG (2011). Water Pricing Policy in Canada. Water Pricing Seizing a Public Policy Dilemma by Horns, 1–7.

Wichman, CJ (2014). Perceived price in residential water demand: Evidence from a natural experiment. *Journal of Economic Behavior and Organization*, 107, 1–16, doi: 10.1016/j.jebo.2014.02.017.

Wichman, CJ (2017). Information provision and consumer behavior: A natural experiment in billing frequency. *Journal of Public Economics*, 152, 13–33

Zetland, D and C Gasson (2013). A global survey of urban water tariffs: Are they sustainable, efficient and fair? *International Journal of Water Resource Development*, 29, 327–342, doi: 10.1080/07900627.2012.721672.