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Percent Change as a Measure of Price Escalation in Water and Energy Utilities

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Abstract

We advance the idea of using percent billing changes as a simple measure of price escalation. This simple yet underused metric may help evaluate rate structure design in public utilities. We illustrate how price escalation may generate useful insight for utility managers by analyzing rate structures from water utilities in British Columbia, Canada. We observe that increasing block rates may send weaker relative price signals to users than a simple constant unit charge, and that low volume users tend to receive the strongest relative price signals. Measuring price escalation may also allow one to quantify the distortions generated by fixed charges. We conclude that analysts may find it useful to include measures of price escalation in their portfolio of metrics to evaluate rate structures in energy and water utilities.

Keywords

charges, conservation, pricing, price escalation, rates, rate design, tariffs

Introduction

Utility managers must balance multiple and competing objectives when designing energy or water tariffs. These competing goals may include economic efficiency, cost recovery, revenue generation, resource conservation, and the equitable treatment of users (Barberán & Arbués, 2009; Dinar, 2000; Thorsten, Eskaf, & Hughes, 2009). When balancing trade-offs, utility managers may turn to various metrics to help them assess if a particular rate structure meets its objective (Honey-Rosés & Pareja, 2018).

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In this article, we aim to invite deeper thinking on a simple, yet underused metric that measures price escalation with the percentage change of a consumer's bill. Scholars working on utility tariff design have largely overlooked price escalation or progressivity as metric upon which to compare rate structures. In this article, we adopt the terminology used by Suárez-Varela and Martínez-Espiñeira (2018) and Suárez-Varela, Martínez-Espiñeira, and González-Gómez (2015) in which price escalation and progressivity are synonymous. We illustrate how measuring price escalation in terms of percentage change of a consumer's bill can help measure the strength of the price signal across billing periods and may quantify how users may perceive billing fluctuations.

It is well-known that relative changes are important to consumers, and this may alter consumption patterns (Agthe & Billings, 1987; Arbués, Barberán, & Villanúa, 2004; Liebman & Zeckhauser, 2004; Olmstead & Stavins, 2009; Wichman, 2014), and as such, we should be attentive to how different rate designs compare in terms of relative price changes. The difficulties in understanding consumer behavior motivates our proposal to re-consider price escalation as a relevant metric to inform tariff design. To begin with, it is often the case that consumers are unaware of the utility rate structure they confront, even if the tariff is described in the bill. This is a problem for researchers and utility managers because our models and rate designs assume consumers make rational decisions in response to utility rates. When modeling consumer choice and behavior, average and marginal price are used as a summary statistic to reflect a rate structure (Arbués, García-Valiñas, & Martínez-Espiñeira, 2003). However, in practice, it is unclear if consumers are aware of these prices. Some authors argue that when modeling consumer behavior, average price is most relevant (Shin, 1985; Wichman, 2014), while others advocate for prioritizing marginal price (Gibbs, 1978) or some combination (Taylor, McKean, & Young, 2004).

How users perceive their utility tariffs becomes even more important when the rate structure is complex (Arbués et al., 2003). In complex tariffs, it is unlikely that users are computing or responding to marginal prices (Arbués et al., 2004; Shin, 1985; Taylor et al., 2004; Wichman, 2014). Strong empirical evidence finds that users may not perceive the rate schedule in the intended manner (Liebman & Zeckhauser, 2004). Liebman and Zeckhauser (2004) found that consumers will undertake rate schedule "ironing" when "an individual facing a multipart schedule perceives and responds to the average price at the point where he consumes (p. 3)." This means that for a user reviewing her current water bill, she will consume less, or more, using her current average price per cubic meter.

While consumers are unlikely to comprehend the complexities of their particular rate structure, there is evidence that users do remember the charge in their previous bill. Empirical studies have demonstrated that consumers respond to a lagged price, in which current consumption responds to previous billing. This lagged effect has been measured in Spain (Arbués et al., 2004) and in North Carolina (USA) (Wichman, 2014). This may be due to an anchoring effect on consumers or merely the result of consumers not having real-time consumption data and needing to wait for their next bill for updated information. Either way, it highlights that consumers are sensitive to past bills and that relative billing changes are relevant for utility users.

Our suggestion to focus on price escalation to inform tariff design is not new. Agthe and Billings (1987) proposed taking a careful look at how relative price changes across consumption levels. Using data from Tucson, Arizona, they find that higher income households are less responsive to price and conclude that increasing block rates (IBR) need to have substantially steeper blocks to improve interpersonal equity in water pricing (Agthe and Billings 1987, p. 285). This article explores a simple approach to measure this feature.

Yet, only recently, Suarez-Varela and colleagues (2015) proposed a cogent measure of price escalation. Their measure compares the average billing change within a set of consumption levels (3 m^3, 5 m^3, 10 m^3, 15 m^3, 20 m^3, 25 m^3, 50 m^3) weighted by the bill at 25 m^3. In their initial proposal, they exclude the fixed component and only look at the variable component of the structure. They then analyze over 900 municipalities in Spain to see which municipal characteristics are associated with greater price escalation in water tariffs. They find that city size, density, precipitation, and water storage availability are negatively associated with price escalation, while economic growth, political stability, and consortium service management are positively associated with greater price escalation (Suárez-Varela et al., 2015).

In subsequent work, they distinguish a price escalation metric with and without the fixed component of the tariff structure. One interesting feature of the price escalation measure proposed by Suárez-Varela and colleagues is that they weigh the measure according to where users actually fall in the tariff structure. This means that if a structure has high steepness at an extreme consumption value, but no one consumes at that level, this will not affect the value of the metric. This decision to weigh the metric by the proportion of users in each consumption block has important consequences. First, one would need billing information to calculate the metric accurately, or alternatively be forced to simulate what this distribution might be. Second, this makes the price escalation metric sensitive to consumption patterns in the municipality. If residents begin to consume more, this would increase the escalation metric even though the tariff structure has stayed the same. The advantage of this approach is that the measure describes an average price escalation metric for what consumers actually confront in that municipality, rather than a purely descriptive metric about the rate structure as we propose below. It would be useful to understand how sensitive the estimated price escalation measure is to this weighting decision.

In the next section, we formally define our measure of price escalation that differs from the measure proposed by Suárez-Varela and colleagues and describe why it may be useful to utility managers and analysts. We then illustrate how this metric may generate insights with examples from water utilities in Canada. Finally, we conclude with reflections on how price escalation may be used to advance research and practice of rate structure design.

Measuring Price Escalation With Percent Change

A simple yet overlooked measure of price escalation is simply the percent change of the total charge at a particular consumption level with respect to another consumption level. While this measure can be calculated between any two consumption volumes, users are most likely to observe price escalation between billing periods. As utility bills

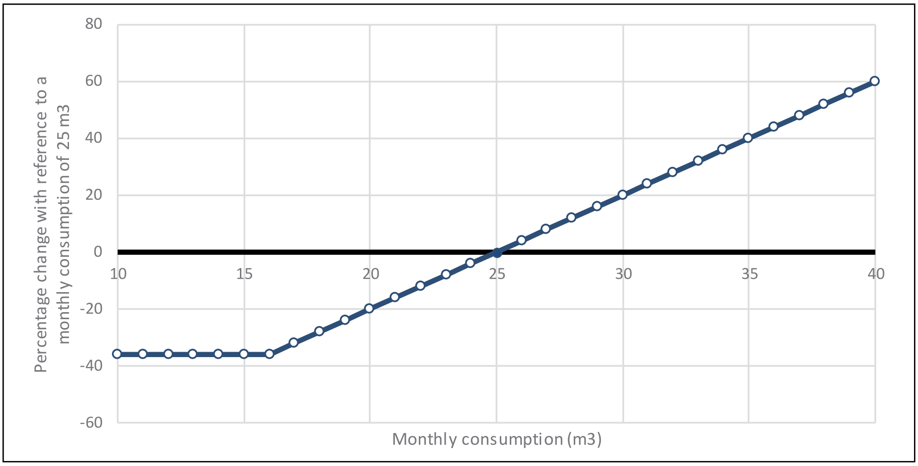

Figure 1. The price escalation curve for the city of Chilliwack (British Columbia, Canada) using percentage change with reference to a monthly consumption of 25 m^3.
Note. The curve illustrates that increasing consumption from 25 m^3 to 40 m^3 will increase utility charges by 60%. It also shows a fixed charge below 15 m^3. After 16 m^3, we observe a constant unit charge, as evident in the proportional increase in consumption and price escalation (e.g., a 60% increase of consumption from 25 m^3 to 40 m^3 leads to the same percent change in the bill).

for most households in developed countries are only a small portion of a family budget, it makes sense to measure billing fluctuations in percentage rather than absolute terms. This measure is able to highlight inter-bill fluctuation even when the price changes are small in absolute terms. Formally, the price escalation observed by one user for any given quantity Q_1, associated with moving to the quantity Q_2 is expressed as

$$Price\ Escalation_{Q_1}(Q_2) = \frac{charge(Q_2) - charge(Q_1)}{charge(Q_1)}.$$

This metric for price escalation measures how quickly charges will increase or decrease given future consumption levels (Figure 1). It is a descriptive metric of the rate structure, and independent from demand variables such as user preferences, household size, or income.

This measure of price escalation is useful for utility managers and analysts for at least five reasons. First, it captures bill changes from an intuitive perspective. While most users are unaware of the details of their rate structure, they are likely to conceive of their bill in percent terms, that is, "my heating bill is twice what it usually is." Therefore, this measure provides us with an intuitive measure that captures perceptions of change from a consumer's perspective. A second advantage is that this measure of price escalation may help utility managers quantify the strength of price signal sent to consumers. Steeper rate structures might motivate resource conservation. Third, this measure of price escalation can help managers identify how a particular tariff sends different price signals to different users (high resource users and low resource users). Fourth, this measure may help utility managers observe the impacts and distortions introduced by particular designs, such as fixed fees. Fifth, this metric is simple to calculate and does not require billing information.

The disadvantage of this proposed metric is that it is a relative measure. The metric is always comparing bill changes between *two* consumption levels, and does not aim to provide a single value for a particular rate structure. To facilitate comparisons across utilities, we might suggest estimating this metric at the consumption value of 25 m^3, as this is a reference point for Canadian water utilities and others globally. It is also the reference point for the escalation metric proposed by Suarez-Varela and colleagues. In theory, one could estimate a single summary metric by taking an average across specific consumption levels (3 m^3, 5 m^3, 10 m^3, 15 m^3, etc.), as Suárez-Varela and colleagues have done. However, we are lukewarm about this approach because we lose the benefit of a simple and intuitive metric from the perspective of the users. We are attracted to the idea that this metric captures how users may perceive price fluctuations. If one aims to develop a single summary metric for a particular municipality, then the measure proposed by Suárez-Varela and colleagues might be the better option. However, for a simple measure that captures how users may be perceiving billing fluctuations, and that permits inter- and intra-utility rate comparisons, then our approach might be the faster way for insights.

Finally, it is important to clarify that price escalation is not the price elasticity of demand, nor slope (first derivative) of the rate schedule, and there is a separate literature on elasticity (Dalhuisen, Florax, de Groot, & Nijkamp, 2003; Marzano et al., 2018).

Insights Derived From Percent Change as a Measure of Price Escalation

To illustrate how our measure of price escalation may be applied in practice, we reviewed utility rate structures in six municipalities in British Columbia, Canada (Table 1), using data from the British Columbia (BC) Municipal Water Survey 2016 (Honey-Rosés, Gill, & Pareja, 2016). In Canada, local governments have complete authority over water utility rates, creating a diverse mosaic of rate structures across the country. In general terms, water charges in Canada are low (Renzetti, 2009) and generally one quarter of European rates (Vander Ploeg, 2011).

High Users Confront Low Escalation

The first insight we derive is that high and low resource users will receive vastly different relative-price signals for the same change in consumption. As consumption increases, the percent change in the total bill will decrease, and as a result, high resource users confront low progressivity. Conversely, low volume users are subject to much stronger relative price signals. While this is entirely intuitive, and perhaps unsurprising, the price signal sent to users is the exact opposite of what most rate

Table 1. The Rate Types of Selected Municipalities in British Columbia, Canada.

City	Rate type	Fixed charges ($)	Charge at 25 m^3/month ($)
Abbotsford	Constant Unit Charge	0	29
Chilliwack	Constant Unit Charge + Minimum Charge	7.2	11
Nanaimo	Increasing Block Rate + Base Charge	1.4	29
Richmond	Constant Unit Charge + Base Charge	4	32
Vancouver	Flat	47	47
West Vancouver	Increasing Block Rate + Base Charge	19	47

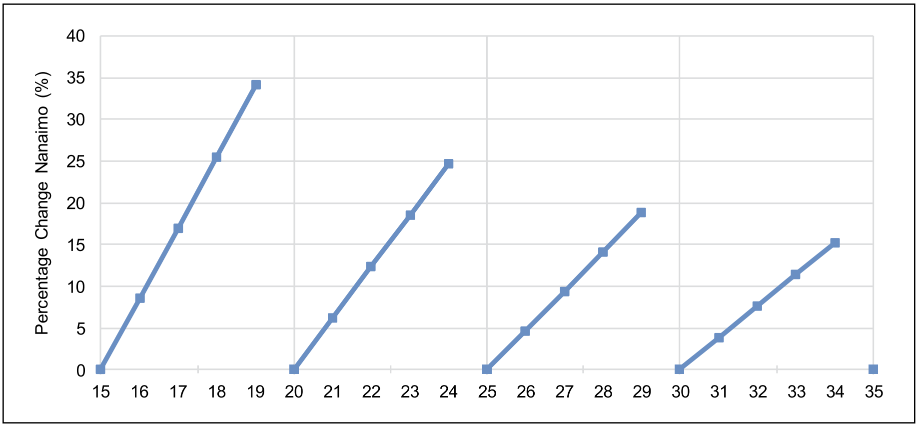

Figure 2. Price escalation as measured with percent change in the city of Nanaimo when using 15 m^3, 20 m^3, 25 m^3, and 30m^3 as baseline consumptions.
Note. This figure illustrates that high resource users confront lower price escalation than low resource users. For example, an increase in consumption of 4 m^3 will increase the bill of a low resource user (baseline 15 m^3) by 35%, while the same increase for a high resource user (baseline 30 m^3) by 15%. Price escalation with percent changes may be calculated for any consumptions level; however, large changes are less realistic for most households, leading us to select 5 m^3 intervals.

designers would like. One would prefer to send stronger price signals to high resource users.

Our measure of progressivity allows analysts to measure, compare, and graphically depict these percentage changes across consumption levels. When we visualize the price escalation over different consumption intervals (Figure 2), we should expect a reduction in progressivity at higher consumption volumes, but the interesting question concerns how quickly the progressivity levels off, or conversely, how managers might maintain it steep for high resource users. Note that the addition of a fixed charge will only exacerbate the leveling effect and reduce the progressivity across all consumption levels. To observe higher progressivity at higher consumption levels, a utility must dramatically increase marginal unit prices at higher blocks. In our example utility in

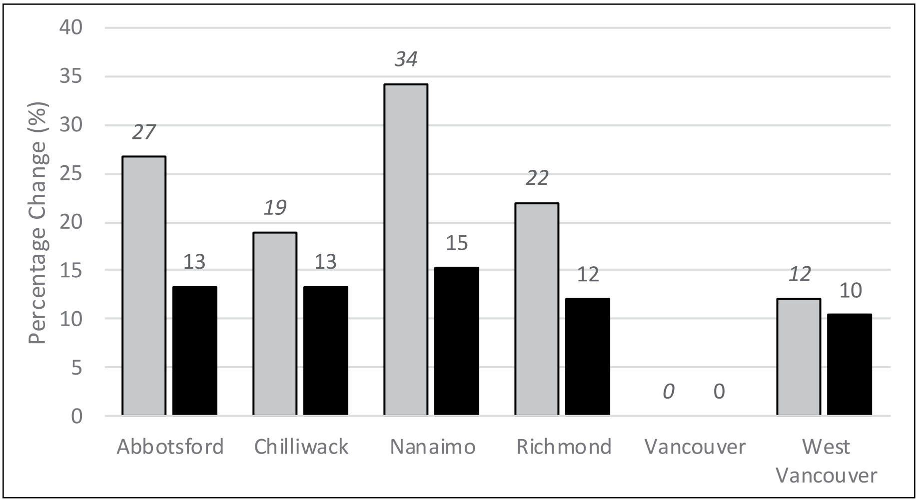

Figure 3. The price escalation when moving from 15 m³ to 19 m³ (left columns) and from 30 m³ to 34 m³ (right columns) for selected municipalities.

Figure 2, Nanaimo has the most aggressive increases in their blocks and yet they too observe a gradual decrease in progressivity among higher consumption volumes. Later, we see how Nanaimo maintains the most progressive rate structure of the group (Figures 3 and 4).

One might argue that Figure 2 is slightly misleading because we observe percentage change in price but do not normalize for consumption or volume (*x* axis). This hides the fact that marginal consumption at lower volumes is larger in percentage terms than marginal consumption at higher volumes. This could be corrected by normalizing on consumption, and this transformation would reduce the steepness of Figure 2, but the underlying pattern would remain the same.

IBR Are Not Necessarily the Most Progressive

Another interesting observation is that the drop in progressivity (from low to high users) persists *even with IBR*, in which high users are charged a higher marginal rate per additional unit consumed. We observe that an IBR does not guarantee that high users will confront stronger relative price signals. Indeed, increases in consumption may only produce small variations in their overall bill. Our proposed metric allows one to appreciate the size of the penalty associated with entering a new block rate, which may be smaller than expected.

For example, in our subset of municipalities, we observe that the price increase associated with an increase in consumption for a low-end user (15 m³/month to 19 m³/month) ranges from 12% to 34% while the same increase in consumption (4 m³/month) for higher users generates a price increase of 10% to 15% (Figure 3). As discussed, we

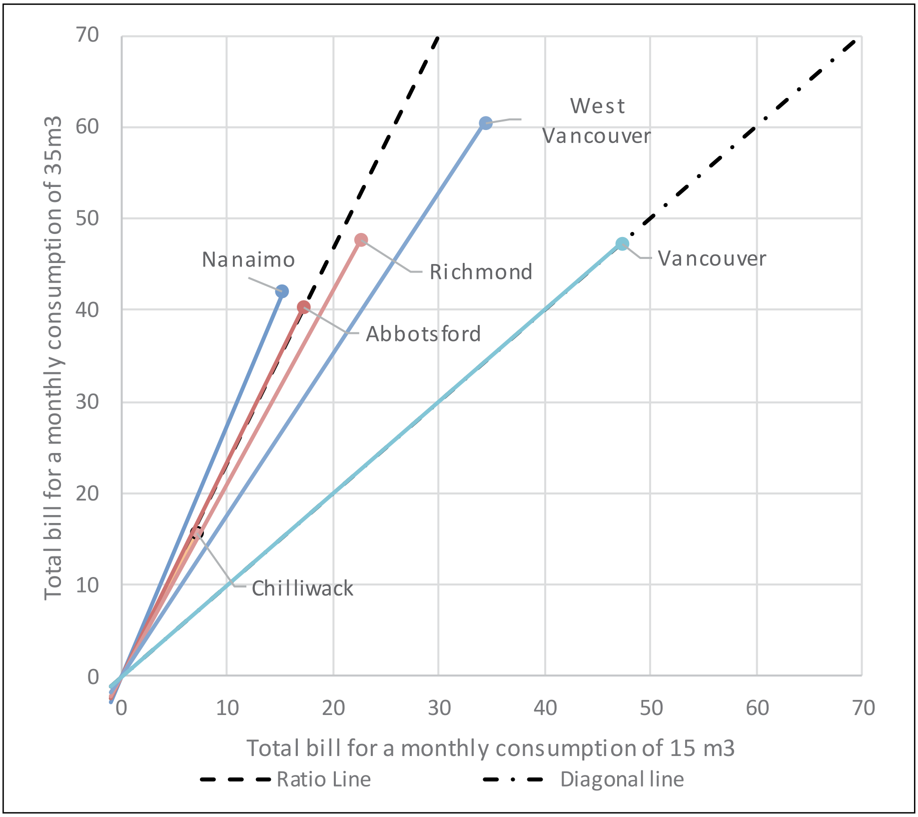

Figure 4. A comparison of rate structure price escalation using a scatter plot with two reference levels of consumption (15 m^3 and 35 m^3) for six municipalities in British Columbia, Canada.

expect high users to confront lower progressivity than low resource users, but the difference across rates varies substantially.

In our subset of example communities, we observe that West Vancouver has an IBR but they do not have greater price escalation than communities with the constant unit charge. In Figure 3, we can appreciate that West Vancouver has lower price escalation than Abbottsford, Chilliwack, and Richmond at both low and high consumption volumes. Only the IBR designed in Nanaimo shows more progressivity than those with the constant unit charge. In this article, we only use a subset of six communities for illustration purposes, but in our larger sample of BC water municipalities, we generally found that IBRs with fixed charges were more like West Vancouver than Nanaimo, in that the increase charges per block did not compensate for the reduced progressivity caused by the fixed charge. In short, the adoption of IBR does not guarantee higher progressivity and constant unit charges without fixed fees may have higher progressivity than IBR with fixed charges.

Measuring Price Escalation Helps Quantify the Impacts of Fixed Charges

Fixed charges are common in utility rate structures because they provide utilities with a guaranteed revenue stream that allows for more reliable infrastructure planning. However, the trade-off with large fixed charges is that it sends weaker price signals to consumers and provides less of an incentive for resource conservation.

There are certainly good reasons to include large base charges in rates; however, fixed or base charges tend to moderate the strength of the price signal sent to consumers. We see this in West Vancouver, where the high base charge reduces the progressivity for high users (Figures 3 and 4). Measuring price escalation in percentage terms allows one to see how fixed charges may impact the strength of the price signal sent to consumers.

Measuring Price Escalation Permits Insightful Comparison Between Utilities

Measuring price escalation with percentage change provides a simple yet powerful metric for making comparisons across utilities. We find it particularly useful to juxtapose rate structures with a scatter plot that can visualize rates at two consumption levels (Figure 4). By placing the utility charge of the lower consumption level on the x axis and the charge at the higher consumption level on the y axis, the plot gains valuable properties.

First, the points furthest from the origin have higher utility charges. In our selected municipalities, we observe West Vancouver charges the most for 35 m^3, while Vancouver the most for 15 m^3. Interestingly, Vancouver has a high charge despite (or because) the city has a flat rate.

Second, this plot graphically illustrates price escalation by literally making the lines steeper. As the point moves toward the y axis, the progressivity increases. In fact, the slope between each point and the origin corresponds exactly to 1 plus the percentage change of the high consumption level with respect to the low consumption level. For our selected rate structures, Nanaimo has the steepest rate at these consumption volumes. And as mentioned, the three municipalities with a Constant Unit Charge have steeper rates than West Vancouver with an IBR plus a base charge.

Third, we add two lines that help facilitate comparison and analysis. Municipalities that have a flat rate will always fall on the $y = x$ line (Vancouver). We also add a line that identifies where a utility would need to be to have the same progressivity as a constant unit charge with no fixed charge. The slope of this line is the ratio between the two consumption levels chosen on the x and y axis. In our example, we use 35 m^3 and 15 m^3 (slope = 2.3). We observe that Chilliwack and Abbotsford charge very different rates but both have a Constant Unit Charge, and fall exactly on this line. Richmond also has a constant unit charge but it is just below the Constant Unit Charge line because it also has a base charge. Thus, the figure allows us to visualize the distortion generated by the base charge in Richmond.

Conclusion

We advance the idea of using percent billing changes as a simple measure of price escalation (progressivity) in water or energy utilities. We distinguish our proposed measure of price escalation—a measure of the rate structure—from other proposed measures that aim to create an index for escalation that accounts for real water use in a particular jurisdiction. We also distinguish our measure from elasticity, which measures how consumers will respond to price changes.

Our proposed measure of price escalation is attractive because of its simplicity and is easily interpretable from the prospective of water users. Furthermore, the insights derived from this measure—such as the observation that higher resource users confront low price changes—are consistent with recent studies that use innovative techniques to study price elasticities with respect to income (Marzano et al., 2018; Sebri, 2014) assuming that high income users are also high resource users.

Comparing rate structures with the lens of price escalation reveals that IBRs may not necessarily send stronger relative price signals to consumers. This is consistent with recent research that finds ambiguous results regarding the effect of IBR rates on price elasticities (Sebri, 2014). Our analysis suggests that a constant unit charge without a base fee can send stronger relative price signals than an IBR. While it is well known that base charges can generate distortions, the graphical presentation we propose allows for easy measurement and comparison of these distortions. We suggest that price escalation should be incorporated into our portfolio of measures to assess trade-offs when considering rate structure designs, particularly among different users groups, or when comparing rate structure alternatives. Percentage change remains an overlooked metric and yet provides a straightforward and versatile measure of the strength of the price signal sent to consumers.

Authors' Note

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