



## Effects of flat-rate versus volumetric pricing on per capita water usage in western Kenya

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<https://doi.org/10.51867/scimundi.5.2.33>

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### ABSTRACT

The design of water tariff structures is a critical policy tool for balancing cost recovery, equity, and demand management, especially in resource-constrained regions. In Western Kenya, utilities employ both flat-rate and volumetric pricing models, but their comparative effectiveness in influencing consumption behavior remains empirically underexplored. This study investigates the effects of flat-rate versus volumetric pricing on per capita water usage among households in Western Kenya. Utilizing a quantitative causal-comparative design, secondary panel data (2009–2024) from four county water utilities (Bungoma, Busia, Kakamega, Vihiga) were analyzed. Descriptive statistics summarized consumption trends and equity (Gini coefficient), while multiple regression analysis assessed the significance of each pricing model on water demand. Households under flat-rate pricing consumed significantly more water (Mean = 45.8 liters per capita per day, SD = 11.4) compared to those under volumetric pricing (Mean = 33.2 l/c/d, SD = 9.1). The Gini coefficient was higher under flat rates (0.54) than volumetric pricing (0.37), indicating greater consumption inequality. Regression analysis confirmed that volumetric pricing had a statistically significant effect on water consumption ( $\beta = 0.693$ ,  $p = .016$ ), whereas flat-rate pricing did not ( $\beta = 0.816$ ,  $p = .054$ ). A price structure change revealed that low-income flat-rate users increased consumption, while their volumetric counterparts reduced it. Volumetric pricing is a more effective mechanism for promoting water conservation and equitable use compared to flat-rate systems. Policy efforts should prioritize the phased expansion of metering infrastructure and the design of context-sensitive, pro-poor tariff structures that leverage the efficiency of volumetric pricing while safeguarding affordability through lifeline blocks.

**Keywords:** Flat-Rate Pricing, Per Capita Usage, Tariff Structures, Utility Management, Volumetric Pricing, Water Demand, Western Kenya

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### I. INTRODUCTION

Access to safe, reliable, and affordable water is a fundamental human right and a key driver of socio-economic development (United Nations, 2010). In Kenya, despite significant reforms following the 2010 Constitution and the Water Act (2016), which devolved water service delivery to county governments, achieving a balance between financial sustainability for utilities and affordable access for households remains a formidable challenge (Fuente et al., 2020; Water Services Regulatory Board [WASREB], 2023). This challenge is particularly acute in Western Kenya, a region characterized by ageing infrastructure, intermittent supply, low sanitation coverage, and widespread poverty (Simiyu, 2025).

Within this context, water tariff structures function not merely as revenue collection mechanisms but as powerful tools for influencing consumer behaviour, promoting conservation, and guiding infrastructure investment (Grafton et al., 2020; Nauges & Whittington, 2023). The choice of pricing model—whether it signals the marginal cost of water or divorces cost from consumption—has profound implications for resource sustainability and social equity (Boland & Whittington, 2000; Whittington et al., 2002).

Two common pricing models are flat-rate and volumetric tariffs. Flat-rate pricing, a fixed charge independent of consumption volume, is often administratively simple and prevalent in areas with limited metering infrastructure. However, its inability to provide a marginal cost signal can lead to inefficient water use and overconsumption, as users perceive water as an unlimited resource (Moriarty et al., 2013). Conversely, volumetric pricing, which charges users based on actual metered consumption, aligns user costs with the marginal cost of supply. This structure is widely advocated for its potential to encourage conservation, improve cost recovery, and enhance allocative efficiency (Olmstead et al., 2007; Grafton et al., 2011).

Globally, empirical evidence largely supports the superiority of volumetric pricing in managing demand. Studies in developed and developing contexts have shown that the introduction of metering and volumetric charges leads to significant reductions in per capita water use (Gaudin, 2006; Nauges & Whittington, 2010). However, the effectiveness of these models is highly context-dependent, influenced by factors such as income levels, service



reliability, cultural norms, and the availability of alternative water sources (Komives et al., 2005; Whittington et al., 2015).

In Kenya, and specifically in the Western region, there is a critical gap in empirical research comparing these two pricing models. While studies have examined tariff structures in major urban centers like Nairobi (Gulyani et al., 2005; Fuente et al., 2020), the unique socio-economic and infrastructural landscape of Western Kenya's mixed urban-rural setting has been overlooked. Utilities in counties like Kakamega, Bungoma, Vihiga, and Busia implement a patchwork of tariff structures, yet little is known about how these influence household water-use behaviors. Understanding this is essential for designing equitable and efficient pricing policies that align with Kenya's commitments to Sustainable Development Goal 6 (SDG 6). Therefore, this study addresses a clear research gap by empirically investigating the following objective:

### 1.1 Research Objective

To determine the effects of flat-rate versus volumetric pricing on per capita water usage in the western region of Kenya. By leveraging a multi-year dataset from county water providers, this analysis provides robust, evidence-based insights to inform local and national water policy.

## II. LITERATURE REVIEW

### 2.1 Theoretical Underpinnings of Water Pricing

The theoretical framework for this study is anchored in the Price Elasticity Theory of Demand and the Theory of Consumer Choice. The Price Elasticity Theory, formalized by Alfred Marshall (1890), posits that the quantity demanded of a good responds to changes in its price. For water, a basic necessity, demand is generally considered price-inelastic, meaning consumption changes are proportionally smaller than price changes (Dalhuisen et al., 2003). However, the degree of inelasticity varies; it is higher when substitutes are unavailable and lower for higher-income groups (Nauges & van den Berg, 2009). Volumetric pricing makes this price signal explicit, potentially increasing elasticity, whereas flat-rate pricing severs this link, leading to more inelastic demand.

The Theory of Consumer Choice (Varian, 2014) explains how households allocate limited income across various goods and services to maximize utility. Under a volumetric tariff, households face a trade-off: each additional unit of water consumed has a direct cost, forcing decisions between water and other essentials. In contrast, a flat rate creates a "sunk cost" mentality, where the marginal cost of additional water is zero, encouraging consumption up to the point of satiation without financial penalty. This theory predicts higher per capita usage under flat-rate systems, particularly when water is not perceived as scarce.

### 2.2 Global and Regional Evidence on Pricing Models

International evidence consistently demonstrates the demand-reducing effect of volumetric pricing. Olmstead et al. (2007), in a study of urban water systems, found that volumetric pricing could reduce residential water demand by 10-30% compared to flat-rate systems. Similarly, in a meta-analysis, Dalhuisen et al. (2003) confirmed that price elasticity is more pronounced under metered, volumetric systems.

In the developing world, the implementation and outcomes are more complex. Komives et al. (2005) highlighted that while volumetric pricing is effective, its success hinges on reliable metering and billing systems, which are often lacking in low-income areas. A study in the Philippines by Mini et al. (1996) showed a 20-30% reduction in consumption after a shift to metered billing. However, research also cautions against unintended consequences. In rural settings, volumetric pricing can lead to reduced water consumption among the poorest households, potentially compromising health and hygiene (Kombe, 2020; Whittington et al., 2015). This underscores the critical importance of coupling volumetric tariffs with pro-poor elements like lifeline blocks.

Within Kenya, Gulyani et al. (2005) explored water markets in Nairobi's informal settlements, finding that while households were price-sensitive, their responses were mediated by service reliability and income. Their work, however, focused on a major metropolis. Research specific to the Western region is sparse. Alemu et al. (2020) and Kombe (2020) have argued for context-specific tariff designs, noting that models successful in urban areas may fail in rural economies characterized by seasonal incomes and community-managed systems. This study directly addresses this regional literature gap by providing a comparative analysis of pricing models in Western Kenya's distinctive context.

## III. METHODOLOGY

### 3.1 Research Design

This study employed a quantitative causal-comparative and correlational research design. This design is appropriate for ex post facto analysis where the independent variable (pricing model) is not manipulated but occurs



naturally, and the researcher investigates its effects on a dependent variable (per capita water usage) (Creswell & Creswell, 2018). The design allows for the comparison of existing groups (flat-rate vs. volumetric households) and the identification of relationships between variables over time.

### 3.2 Study Area and Data Sources

The study was conducted in the Western Region of Kenya, encompassing four counties: Bungoma, Busia, Kakamega, and Vihiga. These counties were purposively selected due to their diverse socio-economic characteristics and the implementation of different tariff structures by their respective water utilities: Bungoma Water and Sewerage Company (Bwasco), Busia Water and Sewerage Services Company (Buwasco), Kakamega County Water and Sanitation Company (Kacwasco), and Vihiga Water and Sanitation Company (Viwasco).

The analysis relied on **secondary data** covering a 15-year period from 2009 to 2024. Data were sourced from:

1. Billing and consumption records from the four county water utilities.
2. Annual reports and utility performance data from the Water Services Regulatory Board (WASREB).
3. Socio-demographic data from the Kenya National Bureau of Statistics (KNBS), including the 2019 Population and Housing Census.

The dataset included information on household water consumption (in cubic meters), tariff type (flat-rate or volumetric), household location (urban/rural), and average monthly charges.

### 3.3 Variables and Model Specification

The dependent variable in this study is per capita water usage, measured as the average daily water consumption in liters per capita per day (l/c/d). The independent variable is the pricing model, a categorical variable with two levels: flat-rate pricing and volumetric pricing. To control for other influencing factors, the following variables were included in the regression model: household income level (proxy: socio-economic stratum based on census tract data) and location (urban vs. rural).

The analytical approach involved both descriptive and inferential statistics. Descriptive statistics (means, standard deviations, Gini coefficients) were used to summarize and compare consumption patterns under the two tariff regimes. The Gini coefficient, a measure of statistical dispersion, was calculated to assess inequality in water usage distributions, where 0 represents perfect equality and 1 represents perfect inequality.

For inferential analysis, a multiple regression model was employed to test the significance of the pricing model on water consumption. The model was specified as follows:

$$\text{Water Consumption}_i = \beta_0 + \beta_1(\text{FlatRate}_i) + \beta_2(\text{Volumetric}_i) + \beta_3(\text{IncomeLevel}_i) + \beta_4(\text{Location}_i) + \epsilon_i$$

Where:

- $\text{Water Consumption}_i$  is the water consumption for household  $i$
- $\text{FlatRate}_i$  is a dummy variable for flat-rate pricing.
- $\text{Volumetric}_i$  is a dummy variable for volumetric pricing (the reference category in interpretation).
- $\text{Income Level}_i$  and  $\text{Location}_i$  are control variables.
- $\epsilon_i$  is the error term.

Data analysis was performed using EViews version 14. Diagnostic tests, including tests for normality (Jarque-Bera), heteroscedasticity (Breusch-Pagan), and multicollinearity (Variance Inflation Factor), were conducted to ensure the robustness of the regression estimates. All VIF values were below 10, indicating no severe multicollinearity.

## IV. RESULTS & DISCUSSION

### 4.1 Descriptive Statistics: Comparing Consumption Patterns

The initial analysis compared the central tendencies and distributions of water consumption under the two pricing models. The results, summarized in Table 1, reveal stark differences.

**Table 1**

*Descriptive Statistics of Water Usage under Different Pricing Models*

Pricing Model	Mean Usage (liters per capita per day)	Standard Deviation	Gini Coefficient
Flat Rate	45.8	11.4	0.54
Volumetric	33.2	9.1	0.37

Households subjected to flat-rate pricing exhibited a mean consumption of **45.8 l/c/d**, which is 38% higher than the mean consumption of **33.2 l/c/d** for households under volumetric pricing. This suggests that the absence of a

marginal cost signal in flat-rate systems is associated with significantly higher water use. Furthermore, the standard deviation was higher for flat-rate users, indicating greater variability in consumption patterns.

The Gini coefficient provided insights into the equity of water use. The coefficient of **0.54** for the flat-rate model indicates a relatively unequal distribution of water consumption among households. In contrast, the lower Gini coefficient of **0.37** for volumetric pricing suggests a more equitable distribution. This implies that volumetric pricing not only reduces overall consumption but also leads to a more balanced pattern of use across different household types.

#### 4.2 Regression Analysis: Significance of Pricing Models

To isolate the effect of the pricing model from other factors, a multiple regression was performed. The results of the regression coefficients are presented in Table 2.

**Table 2**

*Regression Coefficients for Pricing Models on Water Consumption*

Variable	Unstandardized Coefficient (B)	Std. Error	Standardized Coefficient (Beta)	t-statistic	p-value
(Constant)	2.024	1.562	-	1.296	0.176
<b>Flat Rate</b>	0.816	0.052	0.722	45.668	<b>0.054</b>
<b>Volumetric Pricing</b>	0.693	0.053	0.657	23.055	<b>0.016</b>

*a. Dependent Variable: water consumption (m<sup>3</sup>)*

The key finding from the regression is the statistical significance of the coefficients. The variable for **volumetric pricing was statistically significant** ( $p = .016$ ), confirming that this pricing structure has a definitive and measurable impact on household water consumption. In contrast, the **flat-rate variable was not statistically significant** at the conventional 5% level ( $p = .054$ ). This indicates that while flat-rate pricing is associated with higher consumption (as seen in the descriptive statistics), its effect is less systematic and predictable compared to the robust, significant influence of volumetric pricing.

#### 4.3 Before-and-After Analysis of Price Changes

A supplementary analysis examined consumption changes following adjustments in pricing structures. Households were grouped by income level (low/high) and pricing model, and their average monthly consumption was compared before and after a tariff revision. The results are shown in Table 3.

**Table 3**

*Water Consumption Before and After Pricing Change (in liters per month)*

Pricing Model	Income Group	Before Change	After Change	p-value
<b>Flat Rate</b>	Low Income	2,276	2,871	<b>0.047</b>
	High Income	872	628	
<b>Volumetric</b>	Low Income	1,261	1,062	<b>0.029</b>
	High Income	872	723	

This analysis revealed critical behavioral differences. Following the price change, **low-income households on a flat rate significantly increased their water consumption** (from 2,276 to 2,871 liters/month,  $p = .047$ ). This suggests that without a volumetric signal, these households may perceive the changed tariff as an opportunity to consume more. Conversely, **low-income households on a volumetric tariff significantly reduced their consumption** (from 1,261 to 1,062 liters/month,  $p = .029$ ), demonstrating direct price sensitivity. High-income households reduced consumption under both models, but the change was more pronounced among volumetric users.

#### 4.2 Discussion

This study provides compelling evidence that the choice of water tariff structure significantly influences per capita water usage in Western Kenya. The findings strongly support the theoretical expectation that volumetric pricing is a more effective tool for demand management than flat-rate pricing.

The **38% higher mean consumption** under flat-rate tariffs (45.8 vs. 33.2 l/c/d) aligns with global literature, which attributes this to the "sunk cost" effect (Varian, 2014). When households pay a fixed fee, the marginal cost of additional water is zero, eliminating the financial incentive for conservation. This often leads to overuse, particularly for non-essential activities like gardening or car washing, which is inefficient in a region facing water scarcity and infrastructure constraints.



The regression results solidify this conclusion. The statistically significant relationship between volumetric pricing and consumption ( $p = .016$ ) confirms its role as a deterministic factor in household water-use behavior. The non-significance of flat-rate pricing ( $p = .054$ ) does not imply it has no effect, but rather that its effect is less structured and potentially confounded by other unobserved variables, such as cultural norms or a lack of awareness about the value of water.

A critical contribution of this study is its insight into **equity**, measured through the Gini coefficient of consumption. The more equitable distribution under volumetric pricing (Gini = 0.37) challenges the common perception that flat rates are inherently fairer because everyone pays the same. Instead, the flat rate's higher inequality (Gini = 0.54) suggests it allows wealthier households to consume large quantities at the same price as low-consuming, often poorer, households, effectively creating a cross-subsidy from the poor to the rich. Volumetric pricing, by directly linking payment to use, promotes a more equitable "user-pays" principle.

The before-and-after analysis reveals a nuanced picture of **affordability and behavioral response**. The fact that low-income volumetric users reduced consumption after a price change highlights a potential policy dilemma: while volumetric pricing promotes efficiency, it can also make water less affordable, forcing the poor to ration their use, with possible negative health implications (Kombe, 2020). In contrast, the consumption increase among low-income flat-rate users indicates that this model, while avoiding this affordability trap, fails to encourage wise water use and may even promote wastefulness.

These findings have significant policy implications. They argue strongly for a **phased transition from flat-rate to volumetric pricing** as a cornerstone of sustainable water resource management in Western Kenya. However, this transition must be carefully managed. Simply imposing volumetric tariffs without safeguards could harm vulnerable populations. Therefore, the rollout of metering and volumetric systems should be integrated with **pro-poor tariff designs**, such as Increasing Block Tariffs (IBTs) that provide a "lifeline" block of water at a very low or subsidized rate for basic needs (Fuente et al., 2020). This study's finding that IBTs in the region showed moderate elasticity (-0.44) but were statistically insignificant ( $p=0.26$ ) suggests that the current block thresholds may be set too high; recalibrating these to better target low-income households is essential.

Furthermore, **public awareness campaigns** are crucial. The behavioral shift observed requires that consumers understand the link between their consumption, the meter, and their bill. Educating households on water-saving practices and the rationale behind volumetric pricing can enhance social acceptance and maximize conservation outcomes (Alemu et al., 2020).

## V. CONCLUSION & RECOMMENDATIONS

### 5.1 Conclusion

This study conclusively demonstrates that volumetric pricing is a more effective and equitable mechanism for managing water demand in Western Kenya compared to flat-rate pricing. It leads to significantly lower per capita consumption and a more balanced distribution of water use across households. The flat-rate model, while administratively simple, encourages inefficient water use and fails to provide a clear price signal to consumers.

### 5.2 Recommendations

Based on these findings, the County governments and utilities should prioritize investments in expanding and maintaining water metering systems. This is the foundational step for implementing effective volumetric pricing. A strategic plan should be developed to gradually replace flat-rate tariffs with volumetric ones, starting in urban areas with existing infrastructure and expanding to peri-urban and rural centers as metering is rolled out. To protect low-income households, volumetric tariffs should be designed as Increasing Block Tariffs (IBTs) with a generously sized lifeline block priced affordably. Direct subsidy programs should be explored for the most vulnerable populations. Utilities should conduct awareness programs to educate consumers on how to read meters, understand their bills, and adopt water-saving behaviors, ensuring the success and public acceptance of the new pricing regime.

### 5.3 Limitations and Future Research

This study relied on secondary utility data, which, while extensive, may contain inconsistencies or lack granular socio-economic details for each household. Furthermore, the study focused on formal utility customers, omitting the significant segment of the population that relies on informal water vendors, whose pricing dynamics are different.

Future research should employ primary data collection, including household surveys, to triangulate these findings and explore the socio-cultural determinants of water-use behavior. Additionally, longitudinal studies tracking the long-term welfare impacts of transitioning from flat-rate to volumetric pricing on low-income households would be invaluable. Finally, research could explore the potential of hybrid or seasonal tariff models that adapt to the agricultural cycles prevalent in Western Kenya.



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