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The Costs of Coping with Water Insecurity

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Abstract

Water insecurity and poor service quality remain persistent challenges in many developing countries, often exacerbated by irregular access. This study examines how urban households in the Dominican Republic respond to water insecurity, focusing on the interplay between service quality, user perceptions, and coping strategies—such as reliance on bottled water and in-home purification. Using a latent class model, this paper identifies both formal and informal user types and shows that affordability metrics are significantly affected by expenditures on alternative water sources, particularly bottled water. Distrust in tap water is generalized and coping mechanisms like purification and storage provide only limited financial relief. These findings highlight the hidden costs associated with irregular access and low-quality services, mostly affecting vulnerable population. Furthermore, widespread informality and coping costs obscure unmet demand and distort affordability assessments. Accurate affordability measures are essential for evaluating welfare changes, sizing market potential, and justifying infrastructure upgrades. Formalizing services and improving quality can unlock scalable, financially viable investments.

Keywords: Water insecurity, Water consumption, Water affordability, Water quality, Tap water drinkability.

JEL classification: L95, Q21, Q23, Q25, Q28.

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1 Introduction

One in three people lack access to safe drinking water and, despite its essential nature, today it is easier in a developing country to provide access to a cellphone than to provide access to drinkable water [8]. This difficulty is largely explained by a persistent and sizable gap in the deployment and adequate maintenance of infrastructure to supply this service, which in turn originates in insufficient financial capacity due to tariff schemes unable to recover costs in pro of ensuring affordability. However, despite the objective of preserving affordable water services, in many cases a large share of the population faces precarious piped water connections and low quality, unreliable services that ultimately undermine their welfare [16, 17, 2]. This paper explores how households respond and what the implications are for affordability and consumption when faced with unreliable water services.

This paper examines how water insecurity influences household attitudes, coping practices, and overall affordability.[1] Regarding attitudes, this paper examines beliefs about the drinkability of piped water and user satisfaction. On coping practices, it distinguishes the different sources of water used to meet household needs (e.g., bottled water, truck water), as well as other coping strategies (e.g., purification practices). The paper also differentiates between the type of water service received by the household (i.e., formal user or irregular connections) allowing for meaningful estimations of affordability ratios when accounting for coping expenses and the type of piped water connection.

To explore these questions from a relevant empirical and policy standpoint, the paper focuses on a case study of the urban residential water market in the Dominican Republic, which illustrates common challenges faced by water markets across developing countries. It exhibits low service quality and substantial subsidies, which take the form of informal connections, as well as the more widespread tariff subsidies. Around two-thirds of households have irregular or informal connections through which they do not pay for piped-water.[2] To understand the implications of this problem, this paper compiles a dataset to estimate water affordability, consumption, coping strategies, attitudes and services characteristics for a representative sample of end-users. This tailored dataset allows for construction of affordability measurements that account for all sources of water and different types of users.

The different types of users are identified through a latent class model that accounts for service characteristics and household income. Also, this paper performs regression analyses to ex-

[1] This paper uses the broad term *economic water insecurity* as it encompasses the dimensions of quality, reliability, and accessibility that affect human well-being[3, 1]. It is also important to note that, from a causal perspective, the context analyzed in this paper aligns with the concept of *economic water scarcity*, defined as a situation arising from insufficient investment or human capacity to meet water demand[5]. This paper will use both terms, noting that when referring to water scarcity in this context, it refers to the economic definition.

[2] In this sample, the exact type and technical quality of water connections for this group are unobservable. However, field observations and discussions with local water specialists suggest that most of these connections, while highly variable in technical quality, are not predominantly illegal. In many cases, dwellings appear to have been originally connected by the water company, but due to institutional or operational limitations, formal contracts were never enacted. As a result, users find themselves in a situation of irregularity rather than outright illegality. Given that the precise characteristics of this group are not directly observable, the paper applies a latent class model to classify users.

plore the interrelations between household characteristics, coping strategies, attitudes about water service quality, consumption and affordability.

The **main findings** are:

- Affordability estimations are meaningful when accounting for the type of connection. In this case study, two types of users are identified: formal (25% of the sample) and informal (75%). In contrast to formal users, affordability measures for informal users do not capture spending on piped water because they do not pay for those services. Informal user access to piped water is highly heterogeneous in terms of service quality and even household income levels. Therefore, a metric that fails to capture these distinctions reflects a dysfunctional water market rather than the household's capacity to afford adequate water services. In this context, informal connections represent a form of highly regressive hidden subsidy that carry an important social cost.
- In the case of water consumption—particularly in contexts of low quality and high scarcity of piped water— informative affordability measures should also account for spending on alternative water sources to cope with this situation. Affordability ratios considering only piped water are below 3% across all income groups and user types. When accounting for alternative water sources, the ratios for informal and formal users range from 4.4%-5.5% in the lowest income group to around 1.5% in the higher income group, respectively. Notably, among formal users, the income shares allocated to bottled water and trucks is similar to that allocated to piped water.
- The volume of water consumption appears to be linked to the by type of connection and affordability. Consumption from other sources (i.e., trucks) is mostly present among informal users. Bottled water consumption is between 2-3 liters per person per day across all user types. As expected, consumption of all water sources-piped, bottled, others-, increases with income.
- Underlying the large spending share on bottled water, there is a widespread belief that piped water is not suitable for direct consumption. This belief appears to be grounded in perceptions of low physical quality of water which aligns to the reported practice of avoiding drinking tap water, as well as with coping practices (bottled water consumption and spending). Other coping strategies—such as using purification tablets—help reduce both the consumption and cost of bottled water, thereby improving overall water affordability to some extent. However, this coping strategy is only present in 14% of the sample.
- Lower levels of continuity in the piped water supply appear to hinder consumption, even when coping practices are in place. For example, the presence of water tanks and pumps shows only a moderate (statistically no-significant) positive correlation with consumption levels, suggesting that these strategies may not fully offset the severity of water insecurity.
- There appears to be a degree of substitutability between the quality of piped water services and the consumption and spending on bottled water, which also affects overall affordability.

Better perceptions of physical piped water quality, continuity and pressure are all correlated with greater drinkability beliefs and satisfaction levels. Overall, access to better piped water appears to improve affordability. This suggests that water service improvements may lead to changes in attitudes and practices that enhance overall affordability.

This paper bridges two streams of **water economics literature** that have progressed unevenly: (i) water affordability and (ii) coping strategies. Water affordability is the largest body of literature in developing and developed countries addressing the definition of water spending, income, relevant thresholds, and empirical performance across different geographies and socioeconomic consumer profiles. Common thresholds suggest that water expenses exceeding 3–4.5% of household income are unaffordable [4, 14, 11]. The closer study in this stream is [11]. Martínez-Espineira and Pérez-Urdiales (2025) is a very interesting and comprehensive analysis, which calculates affordability ratios by accounting for different water sources across income groups in several Latin American countries. The authors find that piped water is unaffordable for the bottom 20% of the income distribution in all countries considered, except the Dominican Republic. However, the authors based their results on imputed values for household income and did not address other coping mechanisms or beliefs, nor distinguish between different types of users.

On the other hand, the literature on coping strategies shows how higher income households are able to more intensively use and combine multiple coping strategies such as storage, treatment and sourcing alternatives ([10]; [15]). In particular, resorting to bottled water has been well documented when quality of water is low (e.g., [18]). However, this branch of literature is more limited likely because it requires specialized surveys.

The **contribution** of this paper is two-fold. First, it connects different streams of the literature: water affordability and coping strategies. It shows how coping strategies are linked to water service quality and costs. Second, it expands the empirical analysis by including beliefs on piped water drinkability and satisfaction, and by distinguishing the types of users. The analysis of user types (formal vs. informal) is a particularly relevant contribution to policy and the evidence base for developing countries where irregular, poorly maintained water connections are common. That is, without accounting for the type of connection, the affordability ratio would be misleadingly reporting lower levels, instead of a hidden subsidy in the water market.

This paper also outlines **evidence of development challenges in the water sector that need to be addressed to design more effective interventions and strengthening impact measurement**. The findings are particularly relevant to development finance institutions([6] [7]) that prioritize measurable progress in access to safely managed drinking water and sanitation as part of their operational focus on sustainable, resilient, and inclusive infrastructure. By emphasizing user heterogeneity—specifically the distinction between formal and informal water connections—the paper highlights the need for nuanced affordability metrics and targeted strategies to expand regular, adequate connections, informing evidence-based design of policies responsive to the realities of those most affected by water insecurity and poor service quality. Crucially, the analysis documents that widespread informality and high coping costs, such as bottled water purchases, conceal significant unmet demand and distort conventional affordability assessments. These hidden burdens more heavily affect vulnerable populations, not only undermining equity but also obscuring the market potential for water services. This presents both challenges and opportunities to attract much needed investment to the sector: formalizing services and improving water quality and reliability are essential to build user trust, increase satisfaction, and enable scalable, financially viable infrastructure upgrades. To support this, affordability metrics must be refined to reflect all water sources and user types, allowing for more accurate evaluation of welfare benefits, clearer sizing of market potential, and stronger justification for investment decisions.

The next section presents the dataset and descriptive stylized facts of the case study. Section three presents the methodology used to address each research question. Section four present the results. Section five concludes by commenting on the limitations of this paper, areas for further research, and implications for unlocking investment in the water sector.

2 Data

The data comes from a representative sample of urban households in the Dominican Republic, a case study that highlights characteristic challenges of water markets in developing countries. It still has not achieved universal access to piped water, with urban coverage at 75.6% in 2022 (ONE, 2024). Piped water services suffer from reliability issues and heavily subsidized tariffs (World Bank, 2021). A large proportion of residential users have irregular water connections, meaning they do not pay for the service even though they have access to piped water within the dwelling or pay a fixed amount for accessing a piped connection outside the dwelling. The analysis distinguishes households by both their type of piped water connection—formal or informal—and their income level.

The data collection method was tailored to study the affordability of water, accounting for different sources of water. Table 1 presents descriptive statistics, categorized by household income classification. The income classification is based on the poverty line established by the government. If the income per capita falls below that cut-off, the household is classified as "poor." If the income per capita is higher than the poverty line but lower than twice that reference, it is classified as "non-poor." Households with income per capita greater than twice the poverty line are classified as "higher income."

As shown in Table 1, the income classification helps differentiate several characteristics of water services. The share of households with a piped water connections within the dwelling increases with income. In the sample, 74% of households have this type of connection, which is consistent with the previously mentioned national statistics for urban areas. Similar patterns are observed for having a water meter, access to sanitation, and spending on water from different sources (piped, bottled, and other sources). Note that the statistics on water spending include zero values, however there is a large number of households not paying for utility water. Approximately 32%, 99%, and

Table 1: Descriptive statistics

	Income Classification			
	Poor	Non poor	Higher income	Total
N	1,138 (55%)	569 (27%)	370 (18%)	2,077 (100%)
Water grid access	.7 (.46)	.76 (.43)	.84 (.37)	.74 (.44)
Has meter	.081 (.27)	.16 (.37)	.24 (.43)	.13 (.34)
Spending on water grid ss	73 (191)	118 (253)	149 (259)	99 (225)
Spending on water, domestic use	434 (474)	639 (786)	792 (713)	578 (652)
Spending on bottled water	355 (274)	389 (408)	384 (342)	370 (329)
Has grid sanitation (1/0)	.2 (.4)	.3 (.46)	.31 (.46)	.24 (.43)
Drink from the tap	.053 (.22)	.021 (.14)	.022 (.15)	.039 (.19)
Belief-tap water is drinkable	.091 (.29)	.054 (.23)	.062 (.24)	.076 (.26)
Satisfaction with piped water ss	.69 (.46)	.69 (.46)	.69 (.46)	.69 (.46)
Tap water continuity (0-100%)	.43 (.42)	.37 (.4)	.43 (.41)	.41 (.41)
Tap water pressure	.45 (.5)	.42 (.49)	.44 (.5)	.44 (.5)
Percep. of physical quality	.45 (.5)	.45 (.5)	.43 (.5)	.44 (.5)
Water purification	.12 (.32)	.15 (.36)	.17 (.37)	.14 (.34)
Water Storage	.71 (.45)	.74 (.44)	.68 (.47)	.71 (.45)
Water Storage + Pump	.12 (.32)	.24 (.43)	.33 (.47)	.19 (.39)
Income per capita	3,330 (1,414)	8,155 (1,548)	23,334 (19,594)	8,215 (11,127)
Gender of household head	.52 (.5)	.6 (.49)	.67 (.47)	.57 (.5)
Age of household head	50 (15)	51 (14)	53 (13)	51 (14)
Household size	4.1 (1.7)	3.5 (1.5)	3 (1.5)	3.7 (1.7)

Note: This table presents the averages per income classification. For N, the parenthesis show the share of sample per group. For the rest of the variables, parenthesis show the standard deviation.

99% of the sample report positive monthly spending on piped water, bottled water, and other sources, respectively. “Other sources” includes water delivered by trucks.

However, beliefs about drinkability, actual drinking-from-the-tap, as well as continuity, pressure and physical quality of piped water supply are all very similar across income groups. These statistics indicate a dire generalized situation. For example, only 7.6% of the sample declare thinking that tap water is drinkable, and only 3.9% report drinking from it (less than 1% of the sample report drinking but not believing it is drinkable, primarily among lower-income households). On the other hand, piped water supply is available only 40% of the time (as measured by continuity) and, similarly, only in 44% of the cases it is regarded as of adequate physical quality.

Consistently, coping strategies (i.e., water purification, having water storage) are also similar across groups, though households in the higher income group are more likely to have a pump. Still, it is interesting to note that only 14% of household report water purification practices. Most households (70%) have water storage equipment and around 20% also have a pump to address low pressure.

3 Methodology

This section describes the latent class model implemented to identify the different user types; the steps used to estimate affordability and consumption; and the approach taken to explore how the characteristics of piped water service, user beliefs, and coping strategies are correlated with affordability and consumption.

3.1 Types/classes of piped-water users

As noted in the descriptive statistics table, the water market under review presents considerable heterogeneity even within income groups. For example, even in the higher-income group, piped water access remains relatively low at 84%, and service continuity is only around 40%. This raises the question of whether there are unobserved subgroups or types of users relevant to characterize water affordability problems. Therefore, this paper establishes a Latent Class Model (LCM) that allows inference of the type of user (i.e., the class not directly observed) from a set of observable users characteristics.

$$\text{type} = h(\text{connection, meter, bill, continuity, pressure, physical quality} \mid \text{income}) \tag{1}$$

The selection of variables is based on the inspection of the descriptive statistics in Table 1. Table 1 suggests that the status of households as users can be differentiated based on key dimensions such as access to a piped water connection within the dwelling, having a meter, and paying for utility services. Those dimensions are also relevant from the sectoral point of view. For simplicity of presentation and model parsimony, the number of classes that type can have is assumed to be equal to two.[3] This also largely captures the main utility perspective that distinguishes only between clients and users who do not pay for their services. Also, h represents the likelihood function of the proposed latent class model to identify the user *type*. For this application, the assigning to each type is based on the predicted probability at a cut-off of 0.5. It is expected that this non-arbitrary classification will also provide empirically meaningful differences among groups. This will be verified by examining the statistics of the variables used in the classification (measurement variables), as well as other variables in the dataset (e.g., piped-water purification practices, storage, access to sanitation).

The likelihood function of the proposed latent class model is the joint probability of the observed outcomes (y_{ij}), expressed as a mixture over latent classes ($C = c$). For each observation i, the model computes the probabilities of the six binary(k) and continues(k) outcomes (access to water, presence of a meter, piped-water spending, reliability, tap-water pressure, and physical quality of piped water) conditional on class membership, as well as the prior probability of each class given the exogenous covariate ($ln(income)$).

[3] It should be mention that Greene (2021) cautions that determining the appropriate number of classes remains an unresolved problem.

3.2 Affordability ratios

This paper uses a definition of affordability that accounts for all sources of water (i.e., piped water, bottled water, and other sources such as water trucks). Following the literature (e.g., [9], [13],[12]), the affordability measure is expressed as the share of total expenditures on these water sources relative to total household monetary income. As mentioned earlier, in contrast to previous literature, the data collection method used here captures the observed distribution of both the numerator and the denominator, allowing for an accurate representation of the actual distribution of this measure. The affordability measure is expressed as the share of total expenditures on these water sources relative to total household monetary income:

$$\text{AF} = \frac{\sum_i \text{expense on water source}_i}{\text{income}} \tag{2}$$

The affordability ratio (AF) gauges the sum of the expenditure on each source of water i (i.e., piped water consumption paid the utility, bottled water and other sources). Also as noted before, this dataset allows identification of the user type, regular client paying to the utility and informal user who does not make payments. For the later ones, there is not spending on piped water.

3.3 Water consumption estimation

For the case of piped water, this paper exploits the relatively simple pricing scheme in the case study to estimate the water consumed by each household. These are back-engineering calculations based on reported piped water spending (survey data) and water tariffs in the municipality of each household (administrative data). The utilities in the case study apply Incremental Block Rate (IBR) with two consumption blocks. The overall charge also includes a fee for sanitation services that is a percentage of the total water billed (i.e.,20%), and a fixed amount per connection ($40). Therefore, the volumes of piped water consumed are estimated as the spending divided by the incremental tariff applicable to each block, discounting the share corresponding to sewage payment and fixed charge.

There is a large number of users who do not pay for service, so their consumption cannot be estimated. For this group, once calculations are performed for the group that pays, per-capita monthly consumption is imputed based on a Propensity Score Matching procedure (i.e., Mahalanobis) that pairs formal and informal users based on their per capita income and a set of service characteristics (i.e., service continuity, tap-water pressure, perceived physical quality). It is important to note that while this procedure allows for some reference of the unobserved volumes consumed by the informal group, it likely will be a underestimation. This is because, for similar levels of piped water quality and reliability, consumption of irregular users may be larger than those who pay for the service.

For the case of bottled water, given its broad consumption, its unitary price is mostly accurately reported by each bottle capacity in the survey. For non response cases, but with reported bottled water spending, the prices are imputed based on the average household living within the same district. The volume of bottled water consumed is therefore the total spending over the unitary price, expressed in liters.

For other water sources, given low reported consumption and representing a small share of total water spending, it is not estimated in this paper.

3.4 Regression analyses

This section proposes a simple system of equations to explore how service characteristics is correlated with coping strategies, users' attitudes, and affordability ratios.

Specifically, equation 3 shows how household per-capita income and piped-water service characteristics (i.e., perception of physical quality, tap water continuity and pressure) correlate with two dependent coping practices: water purification and water storage (the regressions results are shows separately). Equation 4 uses the same explanatory/independent variables to estimate their correlation with beliefs on water drinkability and satisfaction with the piped-water service. This set-up excludes attitudes from the independent variables in equation 3 because it is recognized that beliefs on piped-water is strongly correlated with service characteristics, and the focus of this analysis is on the direct association between service characteristics and our dependent variables.

In Equations 4 and 5 the dependent variables are affordability measures (bottled water, utility-water, and both) and water consumption (piped and bottled), respectively. For these equations, in addition to the explanatory variables previously mentioned (i.e., household income and the piped-water service characteristics), also introduce water purification practices to explore the correlation with this coping practice. In this set-up, the correlation between coping practices is conditional on income and services characteristics, and can be interpreted as the marginal effect of the actions taken by the households to mitigate service deficiencies. While it is theoretically expected that coping strategies help reduce poor quality/reliability of piped water services, increasing affordability and increasing water consumption, the pronounced deficiencies in piped water services and the relatively low take-up of some coping strategies (i.e., purification methods) make this question empirically interesting.

$$\text{beliefs} = f^1(\text{quality, scarcity,...}) \tag{3}$$

$$\text{coping} = f^2(\text{beliefs, quality, scarcity,...}) \tag{4}$$

$$\text{AF} = f^3(\text{coping, quality, scarcity,...}) \tag{5}$$

In this analysis, f is assumed to be linear such that equations for *coping* and $beliefs$ are estimated through a linear probability , with robust standard errors. All main regressions include the following control variables: type of water connection, having a metered connection, and city indicators of the dwelling.

It is important to emphasize that these regressions do not yield causal estimates. However, the quality and continuity of piped water services are relatively similar across income groups (see Table 1), suggesting that infrastructure deficiencies are widespread and likely stem from severely limited investment capacity among utilities. These generalized deficiencies potentially affect all populations regardless of their observable or unobservable characteristics. Nevertheless, this context is not used as an identification assumption in the analysis, since service type was not randomly assigned.

4 Results

4.1 Types of users

The latent model (Eq. 1) can distinguish user groups with clear differences in relevant service characteristics. According to the classification model, one class/type represents around 25% of the sample, and the remaining 75% belong to the second type. This paper refers to the first group as "formal" users, as they are more likely to have a piped-water connection at home, possess a meter, and pay for services. By contrast, the later group (around 75% of the sample) is named "informal" or "irregular" type. As shown in Table 2, and consistent with Table 1, both user types are distributed across (present in) all income groups. This classification also helps differentiate other characteristics besides those used in eq.1. Annex 1 reproduces the descriptive statistics in Table 1 for these two types and presents the test of differences for all their characteristics.

Table 2: Types of users

	Income Classification			
	Poor	Non poor	Higher income	Total
N	1,138 (55%)	569 (27%)	370 (18%)	2,077 (100%)
Share of formal users	.16 (.37)	.29 (.46)	.45 (.5)	.25 (.43)

Note: This table presents the averages per income classification. For N, the parenthesis show the share of sample per group. For the rest of the variables, parenthesis show the standard deviation.

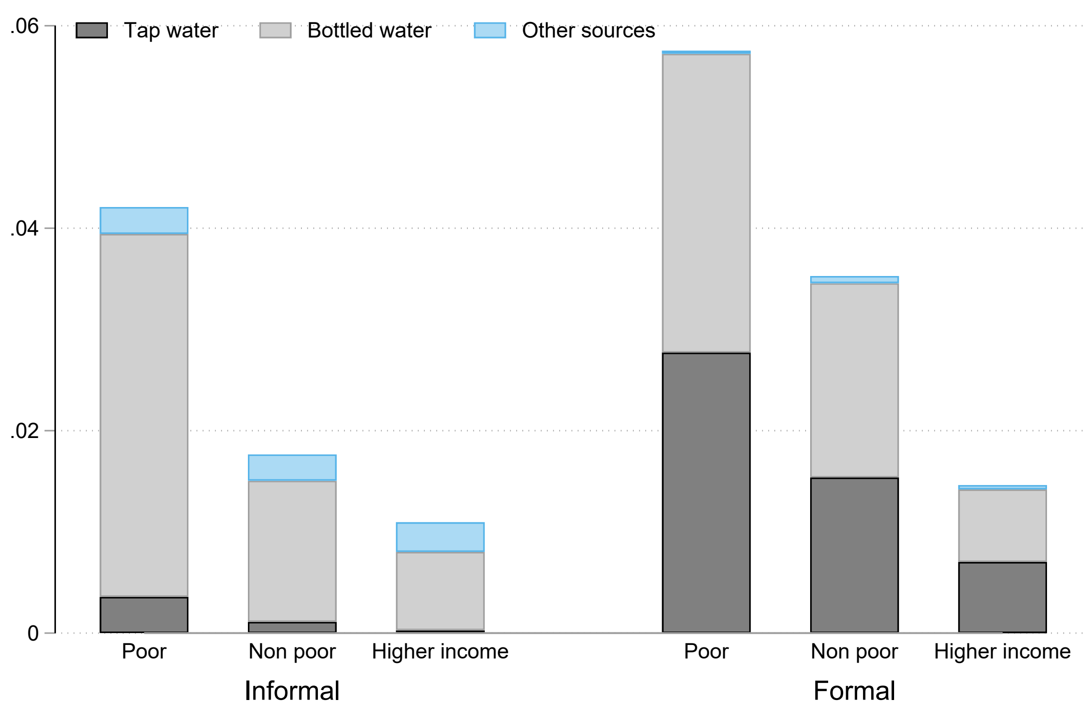
4.2 Water affordability by type of user

The affordability ratios show substantial observed differences between types of users—formal and irregular—as well as across income groups within each type. Figure 1 shows the overall budget share on all sources of water (tap water, bottled water, and other sources). This figure indicates that if only tap water is considered in the affordability estimation, it would return ratios below the 4% threshold in all cases. In the case of irregular users, piped water has no (or very little) share in their budget. This, however, does not fully convey households' spending on alternative water sources to mitigate the scarcity of clean and sufficient utility services. In fact, spending on bottled water represents a sizable share of the overall affordability ratio (AF). Across all user types and income groups, affordability ratios are largely explained by spending on bottled water.

On the other hand, in the case of irregular users—since they don't spend on utility services—most of their spending goes toward bottled water. Also, compared to formal users, spending on other water sources is most significant among irregular users. Given the service characteristics experienced by those users, it is likely that reliance on other sources (i.e., truck water) is due to more severe economic water scarcity, particularly the low continuity of piped water availability (the regression analysis below supports this hypothesis).

Therefore, when accounting for all water sources, Figure 1 shows that the affordability ratios increase significantly. In the case of formal users, the overall water affordability measures more than double when going from considering only utility water to all sources. The lowest income group of the formal users presents an affordability ratio above 5% (well above the 4% reference threshold). Further, only when accounting for all water sources can the water affordability problem be appreciated for informal users. Informal users classified as poor have an affordability ratio of around 4%, while the other two income groups fall below 2%. However, recall that this type of user does not pay for utility services but faces the worst service quality. For additional information, Annex A3 presents the distributional statistics of the estimated affordability ratios by user type.

Figure 1: Water affordability by type of user and income level



Note: Y-axis is the affordability ratio. 0.04 is 4%.

4.3 Water consumption

Figure 2 shows water consumption volumes by type of user, household income, service continuity and affordability levels. Water consumption from "Other sources" is mostly present among informal users. Bottled water consumption is surprisingly similar across groups (i.e., between 60 and 80 liters per month per person). This may be explained by formal users having, on average, better water services and higher incomes, and greater take-up of water purification methods, such that they may be drinking tap water (see Table 2).

Piped water consumption stands between 4,000 and 6,500 liters/month/person for the poor and higher income group, respectively (some outliers drive larger consumption when discriminated by affordability levels). These volumes are consistent with utility estimates in the case study. Volumes across type of user are similar by construction and are only provided for reference purposes. Recall that the volumes of consumption for the informal group are extrapolated because that group does not make payments to the utility.

Interestingly, higher continuity does have a positive correlation with reduced bottled water consumption but not a statistically significant correlation with piped water, as showed in Table A2.[4] On the other hand, these descriptive figures indicate that higher affordability ratios are associated with greater consumption (per capita) and that regardless of coping strategies, low service continuity negatively affects actual water consumption. Both sub-figures also suggest that while improvement in service continuity can increase piped water consumption, it may also imply a higher AF ratio. In this sample, there appears to be some degree of substitutability between piped water and bottled water consumption (and spending), but it does not fully offset the spending weight. See Figure S1 and next section.

Overall, this suggests that, while coping strategies may smooth inconveniences of low service quality, they do not fully offset their negative effect on water consumption. That is, regardless of coping strategies, the water continuity problems preclude consumption of water in this case study.

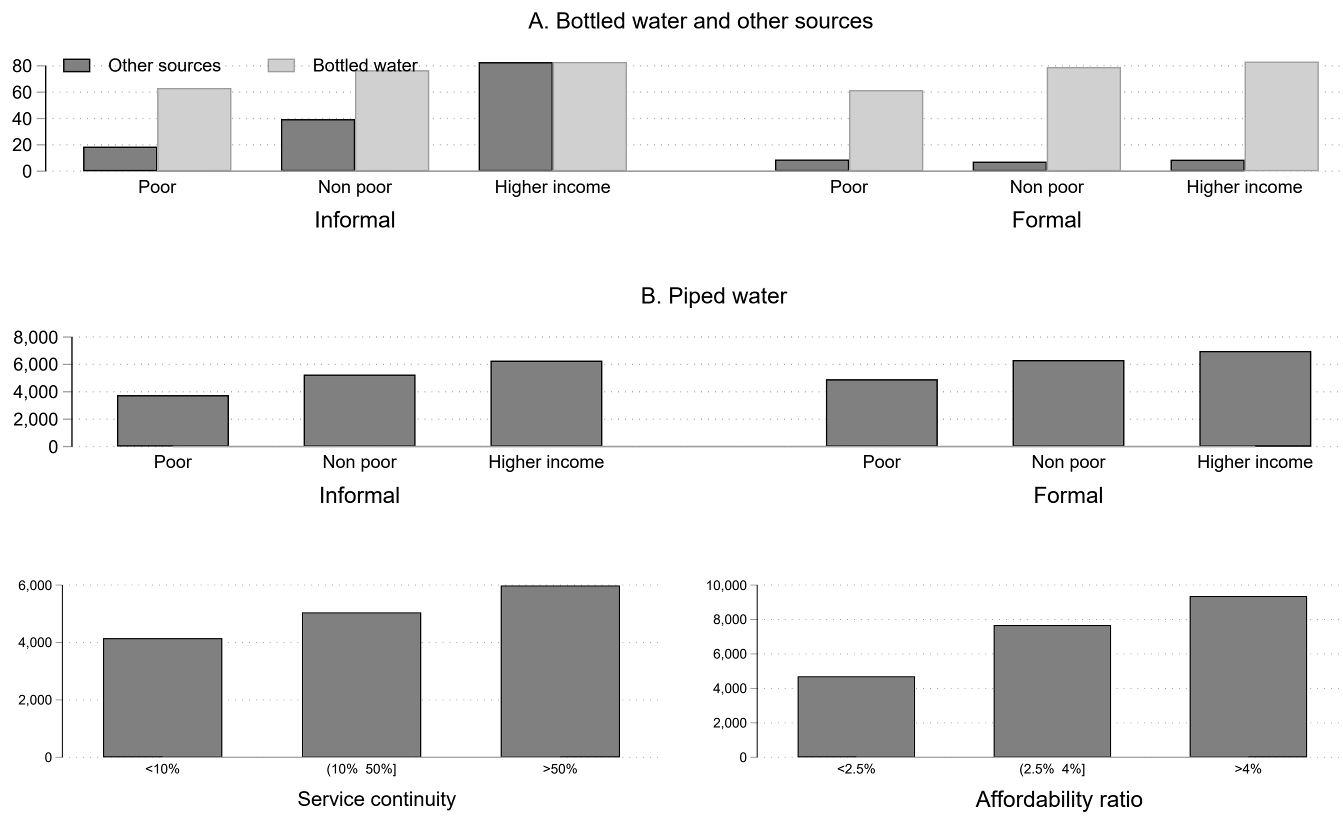
4.4 Coping practices and attitudes

From the above, a follow-up question is what drives coping strategies and attitudes such as drinkability and user satisfaction? The regression results in Table 3 indicate that coping practices vary by income level. Higher income households are able to resort to water storage and pumps to deal with unreliability. As expected better piped water continuity and pressure reduce reliance on storage. The results suggest that households do adopt coping strategies to deal with low quality and scarcity of piped water. It should be noted that the sub-sample that has piped-water purification practices is relatively small (14% of total sample) potentially explaining the reported weak levels of correlation.[5]

[4]The interaction between physical quality and continuity is not significant either, although have the expected, negative, coefficient's sign.

[5]On the other hand, having water storage is widespread in the sample (over 70% of the sample), while having also a pump, to deal low tap pressure, is present in around 20% of the sample. Despite the sample composition, better

Figure 2: Water consumption by type user and income level



Note: Piped water consumption for informal users is estimated based on PSM method. Axis-Y is water billed per month per capita in a household, in liters. Service continuity is represented as the percentage of hours in a month that piped-water is available. Affordability ratio is for piped-water only.

Regarding attitudes, water continuity and pressure quality stand out as the two service attributes with the strongest correlation to piped water drinkability and satisfaction. As expected, better perception of physical water quality more strongly positively correlates (at 1% statistical significance) with drinkability beliefs (better perception of physical piped water quality increases belief in drinkability). Also, improved service continuity and tap water pressure strongly correlate with greater satisfaction. Overall, these results suggest that service improvement may lead to changes in attitudes.

4.5 Water affordability and consumption in the face of scarcity

4.5.1 Water affordability

Table 4 shows how coping strategies, income levels, quality and continuity of piped water are correlated with the affordability ratios. The estimates for water purification practices within the

piped water services (e.g., perception of water quality is 1 if it is good or better continuity of water supply) lead to lower incidence of practicing coping strategies.

Table 3: Coping practices and attitudes

	Coping practices		Attitudes	
	Water purification	Wat. Storage+Pump	Drinkable	Satisfaction
ln(income per capita)	0.0154	0.0779*	-0.00205	-0.00929
	(1.75)	(7.84)	(-0.31)	(-0.85)
Percep. of physical quality	-0.0161	0.0514*	0.0293*	-0.0368
	(-1.05)	(3.00)	(2.75)	(-1.95)
Tap water continuity (0-100%)	-0.0334	-0.143*	0.0336+	0.412*
	(-1.77)	(-6.52)	(2.09)	(17.07)
Tap water pressure	0.00754	-0.0662*	0.0421*	0.199*
	(0.48)	(-3.82)	(3.69)	(10.60)
r2	0.0710	0.141	0.123	0.234
N	2077	2077	2077	2077

t statistics in parentheses. + $p<0.05$, * $p<0.01$

Note: All regressions control for user characteristics; type of water connections, metering status and city dummies.

household appears to improve overall affordability via its component of spending on bottled water. Higher income tend to reduce all AF ratios. Also, favorable perceptions of physical quality of piped water reduces its affordability likely because its greater consumption, but with no significant correlation for bottled water AF. That is, better perception of physical tap water appears not to be strongly correlated with lower spending on bottled water which may be related to the general perception that it is not drinkable (i.e., physical quality may be acceptable for use but not for direct drinking purposes. Also, regardless of physical quality, bottled water consumption may be related to other preferences such as taste).

On the other hand, better piped-water continuity appears to increase the affordability ratio, suggesting that greater piped-water availability tends to increase spending on piped water while having negligible results on overall affordability of this sample (see Column (3)). This is a reasonable estimate since piped-water is documented to be highly subsidized in this case study (low impact on overall AF), and bottled water tends to represent a significant share of total water spending. Recall that this estimate holds for formal users that pay for piped water (i.e., for which the estimations are meaningful).

Overall, these estimates suggest that better quality and availability does not appear to offset the financial burden from coping through acquisition of bottled water.

Table 4: Water affordability regressions

	(1) AF (Bottled-water)	(2) AF (piped-water)	(3) AF
Water purification	-0.00623*	-0.00257	-0.0115*
	(-4.81)	(-1.21)	(-3.65)
ln(income per capita)	-0.0194*	-0.0113*	-0.0265*
	(-19.57)	(-9.84)	(-12.90)
Percep. of physical quality	0.00166	0.00363+	0.00533+
	(1.50)	(2.04)	(2.11)
Tap water continuity (0-100%)	-0.000496	0.00502+	0.00331
	(-0.34)	(2.15)	(0.98)
Tap water pressure	-0.00195	-0.00180	-0.00621+
	(-1.88)	(-0.99)	(-2.24)
r2	0.346	0.267	0.358
N	2077	669	669

t statistics in parentheses. + p<0.05, * p<0.01

Note: All regressions control for user characteristics; type of water connections, metering status and city dummies.

5 Conclusions and implications

5.1 Conclusions

Inadequate water connections and low-quality water services remain pressing challenges in the water markets of developing countries, disproportionately affecting vulnerable populations. This paper shows the empirical differences in water affordability measures when all types of piped connections and all sources of water are considered. As a result, the statistics presented here provide a more accurate assessment of the budgetary burden required to meet essential household needs across different income groups and connection types. Furthermore, the findings reveal that, in the context of high water insecurity, coping strategies do not fully compensate for the lack of service continuity and quality. The paper also presents indicative evidence that not charging users for piped water—through irregular connections as a form of hidden subsidy—negatively impacts utility revenues, thereby weakening the main source of funding needed for essential investments. This, in turn, contributes to lower physical quality and exacerbates water scarcity, with the most severe effects felt by the most vulnerable. Based on the stylized facts presented, it is likely that broader adoption of tap water purification practices, as well as improvements in tap water quality, could help shift consumption patterns, increase substitution between piped and bottled water, and reduce the share of household budgets allocated to water while maintaining healthy consumption levels. However, the study does not evaluate the extent of substitution or its effectiveness in alleviating affordability challenges. The descriptive analysis suggests only weak evidence of such effects. Relatedly, there is a clear need for more robust evidence on how to influence or change public perceptions regarding the drinkability of tap water. The paper does not address the willingness to pay among informal users, nor does it determine the efficient level of service improvements required by utilities to ensure adequate user satisfaction. These remain open questions for future research.

5.2 Implications for Unlocking Investments in the Water Sector

The evidence on the widespread prevalence of informal water supply arrangements in urban areas—and how these arrangements conceal large, unserved customer segments and hidden subsidies—has direct implications for unlocking the sustainable investments needed in the sector. The study's identification of hidden subsidies via informal connections, and its demonstration that coping costs (such as bottled water purchases) represent a major component of effective demand, reveal both risks and untapped opportunities for water operators and investors. This analysis underscores the necessity of a holistic assessment of water market functioning: careful consideration of coping costs, informality, and service quality, together with adequate tariff structures, is essential for accurately sizing and de-risking investment opportunities in water supply markets.

Two key takeaways for enabling investments in the water sector:

- **Water service formalization**: Markets with widespread informal connections and low trust in tap water pose serious challenges to the deployment of investments. The findings highlight the critical need for improvements in reliability and service quality to transition users from informal to formal billing relationships. Targeting service improvement and trust-building can increase revenues and social impact. In turn, de jury and de facto capacity to enforce service formalization—alongside improvements in service trustworthiness—is a prerequisite for achieving a financially viable water market and is fundamental for scalable, sustainable investments in the sector.
- **Measuring affordability**: A nuanced approach to measuring affordability, which includes coping expenses and distinguishes the type of connection, are more informative for policy makers and sector actors and investors. This allows for a more accurate assessment of how households value water quality, market potential, and investment risk. It also helps justify investments aimed at upgrading service quality or expanding formal coverage.

These findings and implications underscore both the potential for market growth through better water services and the importance of those investments for broader social impacts, including affordability, equity, and consumer welfare gains. By addressing informality and integrating coping costs into market assessments, investors can help drive sustainable transformation in the water sector while achieving measurable financial and social returns.

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6 Annexes

Table A1: Stats by users' types

	Latent user type		
	Informal	Formal	Test
N	1,559 (75%)	518 (25%)	
Water grid access	.66 (.47)	.97 (.17)	<.001
Has meter	0 (0)	.53 (.5)	<.001
Spending on water grid ss	24 (88)	322 (336)	<.001
Spending on water, domestic use	597 (660)	421 (571)	.28
Spending on bottled water	355 (297)	417 (408)	<.001
Has grid sanitation (1/0)	.16 (.37)	.49 (.5)	<.001
Drink from the tap	.035 (.18)	.05 (.22)	.11
Belief-tap water is drinkable	.067 (.25)	.1 (.3)	.0079
Satisfaction with piped water ss	.67 (.47)	.75 (.43)	<.001
Tap water continuity (0-100%)	.37 (.4)	.54 (.42)	<.001
Tap water pressure	.39 (.49)	.59 (.49)	<.001
Percep. of physical quality	.55 (.5)	.72 (.45)	<.001
Water purification	.13 (.33)	.17 (.38)	.01
Water Storage	.71 (.46)	.74 (.44)	.12
Water Storage + Pump	.19 (.39)	.2 (.4)	.68
Income per capita	6,853 (7,481)	12,316 (17,496)	<.001
Gender of household head	.58 (.49)	.55 (.5)	.37
Age of household head	50 (14)	53 (14)	<.001
Household size	3.8 (1.7)	3.5 (1.6)	<.001

Note: This table presents the descriptive statistics of the sample comparing formal and informal users. Informal users are those who having access to grid-water do not pay for service.

Table A2: Water consumption Regressions

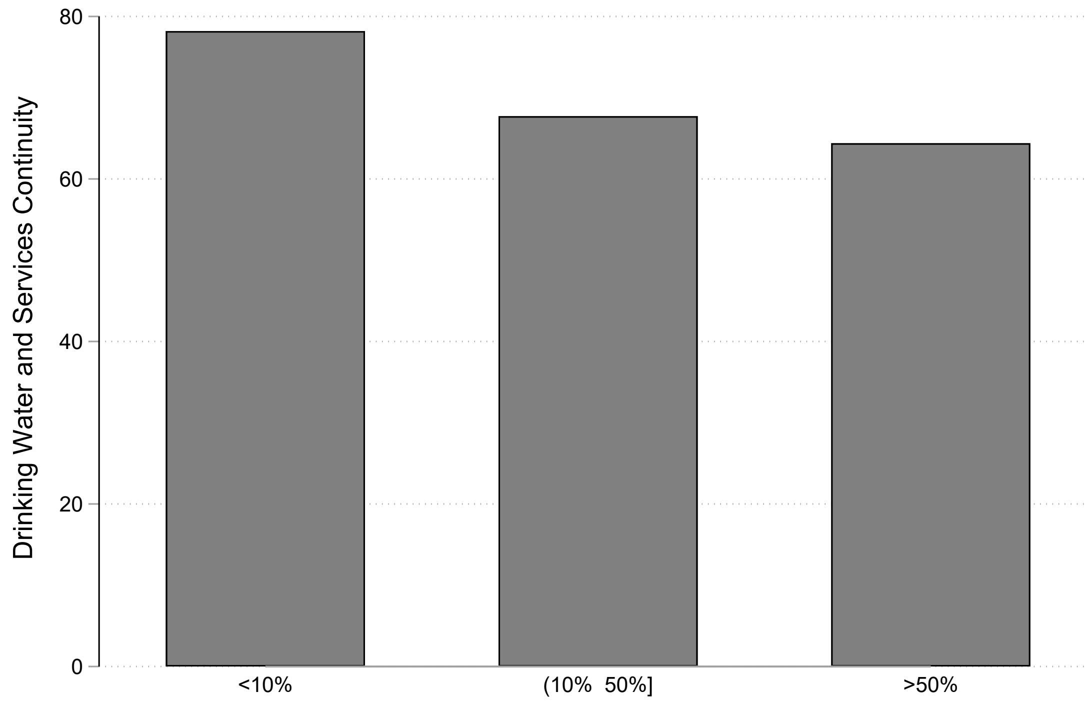
	(1)	(2)
	ln(bottle water)	ln(piped water)
ln(income per capita)	0.0759*	0.234*
	(3.84)	(6.89)
Percep. of physical quality	0.109*	0.154+
	(2.83)	(2.27)
Tap water continuity (0-100%)	-0.104+	0.158
	(-2.40)	(1.95)
Tap water pressure	-0.0228	-0.0536
	(-0.65)	(-0.82)
r2	0.0228	0.116
N	2013	669

t statistics in parentheses

+ and * are p-values lower than 0.05 and 0.01, respectively

Note: All regressions control for type of water connections, meter and city dummies.

Figure S1: Bottled Water consumption by level of water reliability



Note: Axis-Y is water billed per month per capita in a household, in liters. Axis-X shows the service continuity as the percentage of hours in a month that piped-water is available.