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Water affordability measures under multiple and non-exclusive sources in Latin America and the Caribbean

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Abstract

Standard water affordability measures that only account for expenditure on piped water are unlikely to adequately capture the situation of all consumers in developing countries, who often experience water service quality issues and must rely on coping strategies. We construct and compare a series of water affordability ratios including coping costs, and we also adjust these ratios by normative judgements about the need for coping strategies. We use nationally representative household-level data from 18 countries in Latin America and the Caribbean, providing, for the first time, a regional perspective on water affordability. We show that the share of income devoted to water expenses substantially increases when we consider coping costs, particularly affecting the bottom 20% of the income distribution. These findings should be of interest to policymakers aiming at promoting access to safe and affordable water as we also identify the characteristics associated with water affordability issues.

Keywords: water affordability, water quality issues, regulation, Latin America and the Caribbean

JEL codes: Q21, Q23, Q25

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Introduction

In recent decades, increasing attention has been paid to the challenge of ensuring access to water for all, as standards have been steadily rising to consider additional requirements. While early declarations of human rights did not explicitly mention water as a human right, they implicitly acknowledged it because of its interdependence with other explicitly recognized human rights, such as the right to life, to an adequate standard of living, or to health. However, in 2002, the Committee on Economic, Social and Cultural Rights adopted General Comment No. 15 on the right to water (UN, 2003), specifically stating that the human right to water "entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses", which was then reasserted by the United Nations (UN) General Assembly Resolution 64/292 in 2010 (United Nations General Assembly, 2010).

Crucially, the terms "affordable" and "safe" are included, requiring the implementation of measures towards fair and equal access to safe drinking water, at least a sufficient amount of it. To promote this right, the United Nations General Assembly formulated the Sustainable Development Goal (SDG) #6, which aims to ensure the universality of water and sanitation and its sustainable management, as part of the 2030 Agenda. In particular, Target #6.1 provides a comprehensive definition of access to water services, including all its desirable attributes (Vidal et al., 2021), such as affordability, and representing a substantial shift compared to the more lenient definition in the Millenium Development Goals (MDGs).

As pointed out by UNICEF&WHO (2021), SDG Target #6.1 depends on affordability measuring and monitoring to identify those facing payment difficulties and acting more efficiently. However, the lack of consensus when it comes to the definition and the methodology to calculate affordability has hampered the evaluation of progress towards these SDG targets (Salgado Fagundes et al., 2023). Consequently, Indicator #6.1.1 measures the "proportion of population using safely managed drinking water services", ignoring the affordability dimension.

In this context, numerous studies in the water economics literature focus on analyzing water affordability, considering a wide variety of methodological approaches. Most analyses focus on developed areas, such as the United States (US) (Mack and Wrase, 2017; Goddard et al., 2021; Pierce et al., 2020, 2021) or European countries (García-Valiñas et al., 2010b; Martins et al., 2016; Vanhille et al., 2018; Martins et al., 2023). However, empirical evidence is more limited in the case of developing countries, such as those in Latin America and the Caribbean (LAC), where concerns about water service quality are greater than in developed countries. In particular, while the level of access to water on the premises is quite high in LAC, 41% of households with network connections indicate not having access to enough water at some point during the month (Libra and Baquero, 2022). Moreover, as noted by Beard and Mitlin (2021), intermittent water supply may lead to poorer water quality, as the risk of contamination increases due to insufficient water pressure. To address these issues, households need to substitute piped water with other alternative water sources, which often have a higher cost (Beard and Mitlin, 2021). Gómez-Vidal et al. (2022) show that about 50% of their respondents report non-piped sources of drinking water using household survey data from 23 countries across LAC.

Keeping this in mind, to adequately measure water affordability in developing countries, it is crucial to consider the expenditure on alternative water sources. However, previous studies rarely include this information in the computation of the affordability index[1]. As noted by Komarulzaman et al. (2019), most studies on water affordability focus on households' piped water expenditures, leading to a distorted picture of affordability in developing countries where households may also rely on other water sources. In the past years, some studies have focused on water affordability for households not connected to formal water systems. For instance, Gawel et al. (2013) compute different water affordability indices for households buying water from kiosks in Mongolia. While kiosks are the most common water source in their sample, a significant proportion of households rely on other sources. Komarulzaman et al. (2019) provide a measure of hidden affordability for households in Indonesia depending on free water sources, which are of questionable quality, by using the average price of water at the local market as the price they would have paid for good quality water.

While recent studies highlight the impact of water quality issues on household expenditures, analyses based in the Americas have not explicitly accounted for it when calculating this index. For instance, Schur (2017) analyzes the trade-offs between water affordability and household water supply contamination problems using household-level data in the US-Mexico border, where groundwater from the transboundary Mimbres Basin Aquifer is affected by arsenic and fluoride contamination. Their results show that water became less affordable after the implementation

[1]Some exceptions would be Pattanayak et al. (2005), Gawel et al. (2013), Banerjee and Morella (2011), and Nastiti et al. (2017).

of centralized water filtration technologies in Columbus (New Mexico, US), whereas a cheaper solution in Palomas (Chihuahua, Mexico) did not resolve the water quality problem. Beard and Mitlin (2021) discuss different aspects of water access, such as the source of household water, the intermittency of the availability of piped water or affordability, in 15 cities in the Global South including Caracas (Venezuela), Cochabamba (Bolivia), Rio de Janeiro and Sao Paulo (Brazil), and Santiago de Cali (Colombia). The affordability index in this study is hypothetical rather than based on households' actual total water expenditure, as it considers the bill consumers would pay if they were connected and used piped water for all their needs. The results in Beard and Mitlin (2021) indicate that water is most expensive in Latin American cities.

Moreover, the studies focusing on the LAC region tend to consider either a specific country (Revollo-Fernández and Rodríguez-Tapia, 2021) or a few cities throughout the region (Beard and Mitlin, 2021), which may not be representative of the situation in LAC.

Our study is the first to provide and compare different measures of water affordability based on the different water sources reported by survey respondents. To do so, we use nationally representative household-level data from 18 countries in LAC obtained from the Latin American Public Opinion Project (LAPOP)'s AmericasBarometer 2020/2021. Not only do the data offer information on the expenditure on different water sources reported by the household, but they also make it possible to provide a regional picture of water affordability in LAC. Moreover, given that we consider alternative sources to piped water, we propose further affordability measures that consider non-piped water expenditures after we adjusted them for normative reasons. Specifically, we estimate a measure of bottled water expenses that would exclude expenses due to habits or user perceptions of taste or color. Studies such as Doria (2006); Pierce and Gonzalez (2017); Pierce et al. (2019) and Rosinger and Young (2020) show that bottled water consumption is based on preferences and tap water quality perceptions, which are not highly associated with objective risk factors of water safety and quality. In this context, it is important to differentiate between *needs* and *preferences* when computing the affordability ratios. In our exercise, we try to systematically isolate the expense needed from the expense chosen on bottled water.

We also identify the characteristics of the households more likely to devote higher shares of income to water expenses, as well as the attributes of the water service delivered to those households and some regulatory traits of the countries where the households are located.

The paper has the following structure. In Section 1, we discuss different measures and features that previous literature has used to asses water affordability. Section 2 presents the empirical strategy. Section 3 describes the data and variables used in the different stages of the analysis. The results are presented in Section 4. Section 5 provides a policy discussion based on the main findings. Finally, Section 6 concludes by summarizing the main results and policy recommendations.

1 Literature review

As mentioned above, the Human Right to Water (HRTW) and SDGs are often cited to underscore normative aims of equity and sustainability when it comes to access to water (Guissé, 2005; UN, 2003; Nations, 2018; Gawel and Bretschneider, 2016). They provide, whether formally or informally, guidance on how to measure water affordability, for example, by articulating an essential needs volume of water to evaluate affordability (Goddard et al., 2022).

1.1 Defining water affordability

At the most basic and intuitive level, water affordability is understood as the ability to pay for water in relation to one's income. However, many alternative measures have been considered to measure water affordability (Teodoro, 2018; Raucher et al., 2019). The most common approach is based on the ratio expenditure on water to income (Sawkins and Dickie, 2005). Water is then deemed unaffordable for a given unit (a jurisdiction, or a household, most commonly) if the ratio exceeds some predetermined value. This general approach allows for a variety of definitions of water affordability since the "expenditure on water" can be understood in different ways and "income" can also be conceived differently. Moreover, the definition of both the numerator and the denominator of this type of affordability ratio will be subject to normative debates, as well as theoretical and practical difficulties.

Once the above-mentioned ratio is defined and calculated or estimated, it can be compared with an affordability threshold that delineates the level at which water becomes unaffordable. Clearly, the choice of *what is affordable and what is not* is subjective and there is no theoretical reason to specify any one particular level. However, in practice, most studies simply adopt a convention, such as 3% of income, as a benchmark, following the choices made in previous influential works or by prominent international agencies (Pierce et al., 2021).[2]

[2] Fankhauser and Tepic (2007) and Salgado Fagundes et al. (2023) summarize some of the key ratios considered

The shortcomings of measuring affordability according to the most basic form of "ratio" have led to the development of variations in the way that the numerator and the denominator of the ratio are conceived. Indeed, a series of improved measures of water affordability have been proposed, as discussed in Sections 1.3 and 1.4.

1.2 Level of data disaggregation

One perhaps not immediately obvious question is *for whom* to calculate the affordability ratio. The HRTW focuses on individual or household affordability, so affordability should in principle be operationalized at the household level (Pierce et al., 2021). However, in practice, data availability or the intended use, for policy purposes, of the information related to water affordability results in measures at a larger scale. In most cases, the ratio is indeed calculated considering the households' expenditure on water but a representative income in the jurisdiction, as discussed in Section 1.4.

Additionally, some water affordability measures may guide policies and legislation efforts that target individual/household affordability, while other policies will focus on jurisdictional divisions, such as municipalities or even countries. As an example of the former, Martins et al. (2016) use disaggregated household level data to evaluate water affordability in Portugal. They calculate the prevalence of "water affordability problems" as the proportion of households whose water and wastewater affordability ratio (AR) is 3% or higher. Martins et al. (2016) confirm that macro (average) affordability measures can mask serious affordability issues for vulnerable sections of the population. In developed countries, typically expenditures on water only represent around 1% of median household incomes but closer to 3% in the case of poor households (Smets, 2009; Martins et al., 2016).

In terms of more aggregated analysis, as explained by Patterson and Doyle (2021), in the US, the Environmental Protection Agency (EPA) used the earliest metric in the mid-1980s to assess the financial capability of utilities (Environmental Protection Agency, 1984). The EPA aimed to ensure that rates were affordable for a representative level of income in the jurisdiction, considering that utilities have enough financial capability for compliance with the Clean Water Act if average household water bills (combining water and wastewater) were less than 4.5% of the median household income (MHI). This metric, designed to help determine the financial capability of utilities,

by several national and international water governance bodies. According to the literature review conducted by Salgado Fagundes et al. (2023), 90% of those studies reviewed that used a threshold to define tariff affordability used a percentage of income between 2 and 5%.

has often been improperly used as an indicator of household affordability. More recent examples include Goddard et al. (2021), who develop three affordability ratios at the water system scale in California, or Teodoro and Saywitz (2020), who compute affordability ratios for hypothetical households at the 20% income percentile of a nationally representative sample of water and sewer utilities in the United States.

1.3 The effective expenditure on safe water

Most studies of water affordability consider simply water bills as the numerator of the affordability index, the most obvious financial recurrent expenditure associated with water consumption, whether basic (García-Valiñas et al., 2010a; Sebri, 2015), actual (Mack and Wrase, 2017) or hypothetical (Beard and Mitlin, 2021; Cardoso and Wichman, 2022). The bill includes the amount directly associated with the water service but it can also consider other costs, such as those related to sewage collection, wastewater treatment, infrastructure fees, subsidies, and lifelines (Goddard et al., 2022).

However, in jurisdictions where access to piped water in the premises is not the norm, or where the water available through piped connections is not sufficiently safe or reliable, households may also incur "coping costs" (also known as"replacement costs" or "avoidance costs").[3] As seen in different countries such as Colombia, India, Kenya or Nepal, households not connected to formal municipal water systems often pay the highest price for water, as alternatives may be notably more expensive than piped water (Zérah, 2000; Katuwal and Bohara, 2011; Cook et al., 2016; Stoler et al., 2020).

Bottled water is an alternative water source often used when consumers perceive piped water as unsafe (Vásquez, 2017; March et al., 2020; Hamed et al., 2022). While this type of water source is usually considered relatively expensive, Walter et al. (2017) find that, from an affordability perspective, it may be preferred over piped water due to the total costs associated with guaranteeing its reliability and quality. Other alternative sources of water include water vendors, kiosks, neighbours with connections, communal/public taps, and rivers and springs, which may hide the computation of a comprehensive water affordability ratio as the estimation of the associated costs often involves estimates of the value of time and labour involved in accessing these sources (Whit-

[3] The environmental valuation literature exploits this notion when using revealed preference methods to value the quality of water (McConnell and Rosado, 2000; Orgill et al., 2013).

tington et al., 1990). Although having access to several water sources can offer resilience to water scarcity, it normally comes at a greater cost (Daly et al., 2021).

Because they are often not connected to water supply systems through centralised pipe networks, the poorest often pay the highest price for water. Alternative sources like water purchased from vendors and bottled water are much more expensive than piped water, and illegal water connections managed by organised criminal gangs can be even more expensive for households living in slums. When unsafe water requires boiling, fuel costs further increase the burden of obtaining safe water on those households who can least afford it (Allen and Bell, 2011).

1.4 Measuring income

As previously noted, the task of measuring water affordability involves not only an estimation of the different types of costs discussed in Section 1.3 but also an estimation of ability to pay. That is, one must have a measure of income. The question to be asked is, however, not only *how much* income but *whose* income. This is because, especially in the case of developed countries, water rarely leads to affordability concerns for most of the population but it may indeed affect low-income households (Goddard et al., 2021).

Most commonly, aggregate measures of ability to pay include gross income, usually the median household income in the jurisdiction of interest. However, the mean household income[4] or any other moment of the income distribution, such as the first quintile, could be considered instead. For example, much of the recent research effort in the US, and in line with the recommendations laid out by UN (2003), emphasizes the need to consider the financial costs faced specifically by low-income households (Mack and Wrase, 2017; Raucher et al., 2019; Teodoro and Saywitz, 2020), which suggests that, at least in developed countries, affordability ratios are more meaningful when calculated for the poorest quintiles of the income distribution. In any event, as pointed out by Martins et al. (2016), average ratios fail to fully account for differences among households in terms of their water use needs and differences in their income.

Goddard et al. (2021) develop ARs based on the median income but also calculate the corresponding ARs based on the official poverty level as well as half of that level (a "deep" poverty level), pointing out that using multiple measures of water affordability should be more informa-

[4]The mean would be, of course, an even less helpful moment of the distribution, since income is usually quite asymmetrically distributed.

tive than using only one, since they all suffer from limitations. The official poverty level has the desirable characteristic of being routinely available through official statistics in many jurisdictions, providing an obvious "objective" benchmark to define "low-income".

Moreover, for low-income households, due to the seasonal nature of many low-income jobs (Goddard et al., 2022), particularly in less developed countries, it is more difficult to measure income, since the underground economy is more prevalent. In this context, approximating ability to pay by looking at expenditures instead of income might be a more valid approach (Hutton, 2012; Mack and Wrase, 2017). However, the use of expenditures to estimate income will tend to underestimate the latter, simply because expenditure does not include unspent income (Goddard et al., 2022). On the contrary, and as pointed out by Goddard et al. (2022), measures of gross income over-estimate available income, since not all gross income is disposable. Therefore, a measure preferable to but less common than gross income is disposable income (Smets, 2009; García-Valiñas et al., 2010a; Gawel et al., 2013). Recently, the disposable income net of estimated essential expenditures has also been suggested (Teodoro, 2018).

1.5 Affordability ratios

Depending on the abovementioned features, several ARs have been proposed in the literature:

- *The Conventional Affordability Ratio (CAR)*: This most basic ratio measure considers water bills for average water use in a household as a proportion of household income or, in the case of a region, as a proportion of the median household income (Hoque and Wichelns, 2013; Goddard et al., 2022). While this ratio is quite common, it may not fully represent the issues of water affordability faced by those households in the lowest range of the income distribution.

- *The Potential Affordability Ratio (PAR)*: Instead of simply considering the actual expenditure on water, the PAR is based on the estimated costs of water used only for essential needs (Fankhauser and Tepic, 2007; Miniaci et al., 2008; Kessides et al., 2009; García-Valiñas et al., 2010a; Van Abs et al., 2022). This follows the normative value judgement that distinguishes between different uses of water, assuming that water consumption above a certain threshold is "excessive" or "superfluous". Moreover, there is a range of consumption that would be deemed unacceptably low, regardless of what the actual individual choice is. With this in mind, this ratio avoids the measurement error introduced by any over-consumption or under-consumption embedded in actual expenditure amounts (Goddard et al., 2022). The level of water needed is defined in different ways, such as following predefined standards (Cardoso and Wichman, 2022) or computing it based on the estimation of a Stone-Geary demand function (García-Valiñas et al., 2010b; Sebri, 2015) and has been referred to as a "basic water services" (Patterson and Doyle, 2021), an "essential minimum quantity" (Martins et al., 2019), or a "lifeline level" (García-Valiñas et al., 2010b).

One of the main issues associated with this measure is that, in studies focusing on an area with the same water rate, the only source of variation in the data comes from the income variable. As a result, this index may identify problems of income deficit instead of actual water affordability issues (Gawel et al., 2013; Goddard et al., 2022). However, this ratio can be useful to analyze water affordability issues across areas that differ in both water rates and income levels (Goddard et al., 2021).

- *The* AR_{20} *(AR20)*: Davis and Teodoro (2014) proposed the AR20, a variant of the PAR, aimed at signalling the affordability for low-income households of water and sewer costs after their other needs have been met. In this sense, it differs from previous ratios in that it considers disposable, rather than actual income, and it focuses on the bottom 20% of the income distribution.[5] Calculation of the AR20 involves a normative choice about what should be considered an essential need, not only in terms of water itself but also in terms of other household needs when going from "income" to "disposable income" and, more practically, measuring or estimating how much households spend on those essential needs. This type of measure that focuses on the most vulnerable segments of the population is gaining increasing popularity (Teodoro, 2018; Raucher et al., 2019; Van Abs et al., 2022).

1.5.1 Benchmarks against which ratios are compared

As noted before, once the ARs are calculated, they are most often compared against an affordability threshold. Thresholds of affordability have been suggested in the range of 1.5% to 10%, partly depending on which services are considered for the computation. However, the most common

[5] Specifically, Davis and Teodoro (2014) measured affordability after deducting food, housing, taxes, medicine, and home energy expenses from the 20^{th} percentile income of metropolitan regions served by large utilities (serving more than 3300 users).

international standard is that expenditures on water should not exceed 3% of household income, the combined expenditure on water and sanitation being not higher than 5% (United Nations General Assembly, 2010).

1.6 Determinants of water affordability issues

The computation of water affordability indices is often supplemented with an analysis of the characteristics associated with affordability issues, distinguishing between household characteristics, political factors, water utilities' managerial determinants and geographical factors. Among household characteristics, one can consider variables such as income (García-Valiñas et al., 2010a; Martins et al., 2016), household size (García-Valiñas et al., 2010a; Martins et al., 2016), household composition (García-Valiñas et al., 2010a; Martins et al., 2016), ethnicity (Cardoso and Wichman, 2022), age of housing units (Cardoso and Wichman, 2022), house ownership (Cardoso and Wichman, 2022), or water-using appliances in the house (Martins et al., 2016). In terms of political and geographical factors, García-Valiñas et al. (2010a) include altitude, indicators of the position along the left-wing political spectrum of the political party in power, an indicator that municipalities are located on the coast, and indicators of the river basin where the municipality is. Finally, García-Valiñas et al. (2010a) consider also the management type and the number of years since the management of the water supply was transferred to a public corporation.

2 Empirical strategy

2.1 Income imputation

As seen in Section 1, income is one of the main variables of interest in computing a water affordability index. However, as in most household and living standard surveys, our income variable is reported in brackets. In particular, the original income variable is a five-category variable capturing the quintiles of the income distribution for each country. While response rates to this interval-censored question format are higher than to those asking to report exact values (Wang et al., 2013), the computation of affordability measures and regression analysis becomes challenging.

In order to to be able to use the information about income in our dataset to construct water affordability indices, we follow an imputation approach that simulates the distribution of the data reported in brackets.[6] Specifically, we adopt a multiple imputation approach that accounts for the censored nature of the dependent variable (Royston, 2007; Canavire-Bacarreza et al., 2022) by using an interval-regression model. This generalization of censored regressions estimators, such as the Tobit model, makes it possible to model, starting from the (censored or uncensored) values of the extremes of the income brackets[7] reported, the probability that a household's income falls within the underlying income brackets. This approach also allows us to generate the prediction of a continuous measure of income, given the characteristics of the household. In particular, we assume that the latent structure related to our interval variable is given by:

$$Income_i^* = x_i'\beta + u_i^* \tag{1}$$

where $Income_i^*$ is the unobserved log of earned income for household i; x_i and β are vectors of variables related to characteristics of the household[8] and unknown parameters, respectively; and u_i^* is the unobserved error term assumed to be independently identically normally distributed with zero mean and variance equal to 1, so that:

$$Income_i^*|x_i \sim N(\mu(x), \sigma(x)) \tag{2}$$

The latent variable $Income_i^*$ is only observed to fall into the $K+1$ mutually exclusive intervals $(-\infty, a_1)$, (a_1, a_2),..., (a_K, ∞), where a_1, a_2,..., a_K are known. Given that,

$$Pr[a_k < Income_i^* \leq a_{k+1}] = Pr[Income_i^* \leq a_{k+1}] - Pr[Income_i^* \leq a_k] = \Phi^*(a_{k+1}) - \Phi^*(a_k) \tag{3}$$

where $\Phi^*(.)$ is the cumulative distribution function of the standard normal.

Then, the interval-data Maximum Likelihood Estimator (MLE) maximizes:

$$logL = \sum_{i=1}^{N}\sum_{k=1}^{K} d_{ik} ln[\Phi^*(a_{k+1}/x_i) - \Phi^*(a_k/x_i)] \tag{4}$$

[6]An alternative strategy to handle categorical income variables is to assign the midpoint of the income intervals to households in that category (Bhat, 1994). However, as indicated by Hsiao (1983), this method results in inconsistent model relationships. Moreover, given that the income variable is presented in five categories, the variability of the continuous income variable would be substantially reduced.

[7]Note that, to increase the efficiency of our imputation exercise we substituted, before imputing, the undefined censoring limits of the highest income bracket proposed to each household with the high but plausible value of USD 10,000 per month.

[8]Summary descriptives of the variables used in the imputation exercise are reported in Table 8, in Appendix A.

where d_{ik} is a binary indicator equal to one if $Income_{ik}\ \epsilon\ (a_k, a_{k+1}]$ and 0, otherwise.

As noted by Canavire-Bacarreza et al. (2022), the range of values that can be potentially used to impute $Income^*$ lie between the interval boundaries a_{k+1} and a_k. Therefore, the unobserved error term u_i^* is also bounded:

$$u_i^*\ \epsilon\ \left[\frac{a_k - \mu(x)}{\sigma(x)}, \frac{a_{k+1} - \mu(x)}{\sigma(x)}\right] \tag{5}$$

Then, following Canavire-Bacarreza et al. (2022), we can impute values for $Income_i^*$ by getting random draws for u_i^* as follows:

$$\tilde{u_i} = \Phi^{-1}(r_i) \tag{6}$$

where $\Phi{-}1(r_i$ represents the r^{th} quantile for the standard normal distribution, and

$$r_i \sim\ uniform\ [\Phi(\frac{a_k - \mu(x)}{\sigma(x)}), \Phi(\frac{a_{k+1} - \mu(x)}{\sigma(x)})]. \tag{7}$$

Therefore, we can construct:

$$\widetilde{Income}_i = x_i'\hat{\beta} + \tilde{u}_i \tag{8}$$

Using the estimated parameters $\hat{\mu}(x)$ and $\hat{\sigma}(x)$ by the interval-data MLE, we obtain random draws to account for the uncertainty of the regression estimation from the following joint normal distribution:

$$\begin{bmatrix}\tilde{\mu}(x)\\ \tilde{\sigma}(x)\end{bmatrix} \sim \begin{pmatrix}\tilde{\mu}(x) & ,\tilde{\Omega}\\ \tilde{\sigma}(x) & \end{pmatrix} \tag{9}$$

where $\tilde{\Omega} = \hat{\Omega} \times \frac{n}{\tilde{n}}$; $\hat{\Omega}$ is the estimated variance-covariance matrix; n is the sample size; and $\tilde{n}$ is a random draw from a χ^2 distribution with n degrees of freedom.

We obtain $\tilde{\tilde{u}}_i$ as random draws of the form:

$$\tilde{\tilde{u}}_i = \Phi^{-1}(\tilde{r}_i) \tag{10}$$

, where $\tilde{\tilde{u}}_i$ is used instead of $\tilde{u}_i$ to denote the role of the estimated parameters; and

$$\Phi^{-1}(\tilde{r}_i) \sim \ uniform \ [\Phi(\frac{a_k - \tilde{\mu}(x)}{\tilde{\sigma}(x)}), \Phi(\frac{a_{k+1} - \tilde{\mu}(x)}{\tilde{\sigma}(x)})] \tag{11}$$

Then, the imputation of $Income_i^*$ is given by:

$$\widetilde{\widetilde{Income}}_i = x_i\tilde{\beta} + \tilde{\tilde{u}}_i \tag{12}$$

Once the imputed income is obtained, standard aggregation methods, such as the one proposed by Rubin (1987), are used to construct and explain the affordability ratios as if the income variable were fully observed, while taking into consideration the extra variability involved in the use of imputed data.

2.2 Construction of naive measures of water affordability

2.2.1 Basic water affordability ratio

After performing the income imputation, several types of affordability ratios can be calculated. Following the previous literature, we start with a most basic ratio that measures the amount the household declares to spend on piped water monthly as a proportion of monthly household income. For household i, this basic affordability ratio $AR1_i$ is given by:

$$AR1_i = \frac{expense\ piped_i}{Income_i} \tag{13}$$

, where $expense\ piped_i$ is the monthly expense on piped water declared by household i translated into Purchasing Power Parities (PPP) equivalents, expressed in the common measure of US dollars (USD), and $Income_i$ is the interpolated monthly household income, also translated into PPP equivalents and expressed in USD.[9]

2.2.2 Affordability ratios that consider coping costs

The next two affordability ratios we constructed consider different coping costs. Specifically, the second affordability ratio ($AR2$) includes not only expenses on piped water but also expenses on bottled water. For a given household i, this ratio is defined as:

[9] Monetary variables are expressed in PPP to control for differences in price levels between countries and to equalize the purchasing power of currencies when we compute descriptive statistics. The water affordability ratio, given that both its numerator and its denominator are expressed in PPP, remains unaffected by this transformation.

$$AR2_i = \frac{expense\ piped_i + expense\ bottled_i}{Income_i} \tag{14}$$

where $expense\ bottled_i$ is the monthly expense on bottled water made by household i translated into PPP equivalents, expressed in the common measure of USD.

Last, given the information available from the LAPOP dataset, we build a third type of affordability ratio ($AR3$) that takes into account not only expenses on piped water but also on bottled water and water purchased from a truck or street vendor. This ratio is defined for household i as:

$$AR3_i = \frac{expense\ piped_i + expense\ bottled_i + expense\ truck_i}{Income_i} \tag{15}$$

where $expense\ truck_i$ is the monthly expense amount spent on water purchased from a truck or street vendor stated by household i translated into PPP equivalents, expressed in the common measure of USD.

2.3 Construction of adjusted measures of water affordability

The *naive* affordability ratios described in Section 2.2 assume that there is no normative rationale not to accept at face value the estimated/perceived monthly amount (in actual \$'s) respondents state to spend on bottled water. Barring issues of measurement error, this amount is what the calculation of the affordability ratio is supposed to take into account. An alternative normative view of the expense on bottled water, however, may lead us to consider that amount to be an overestimation of the true burden faced by the household. This is because some of those households, to some extent, may buy bottled water not as a coping strategy (because they *need* it) but (wholly or partly) because they prefer to consume it (they *want* it), because it has better taste, it is a habit, it is fashionable, confers status, etc.

A detailed review of the literature on preference versus need to consume alternative water sources, especially bottled water, is beyond our scope. The reader is directed to the works of Doria (2006, 2010), Doria et al. (2009), Massoud et al. (2012), Matos de Queiroz et al. (2013), and, more recently, Rosinger et al. (2018) Rosinger and Young (2020) Pierce and Gonzalez (2017), Javidi and Pierce (2018), and Pierce et al. (2019). These works point at the complexity of the choices between tap water and bottled water and other water sources, which depend of factors (such as ethnicity, country of origin, location, socio-economic status, education levels, trust in the government, or gender) that often have little to do with the quality itself of the tap water supply, thus calling to question, from a normative point of view, whether the expense on bottled water should be included, or fully included, in a water affordability metric.

Our reasoning here is based on the notion of *jointness of consumption*, similar to the one used by Abrahams et al. (2000) when valuing improvements in water quality using the averting behavior approach: "Forms of averting behavior such as use of bottled water and water filters are problematic for researchers investigating willingness-to-pay because households may purchase bottled water and water filters for reasons other than prevention of risk from contaminated water supplies, thus violating the assumption of non-jointness. Other reasons for purchasing filters and bottled water include taste, odor, and appearance relative to tap water." (Abrahams et al., 2000, p. 429)

Therefore, in this section, we further consider measures of water affordability that recognize that not all coping costs must be considered in the numerator of the affordability ratio as essential expenses. First, we analyze the choice of type of water source made by the households. More specifically, we use the results of a Multinomial Logit (MNL) analysis to explain the likelihood of using piped water only, using piped water combined with bottled water, using bottled water only, or belonging to a small group of households that either use trucked water as their main source of drinking water or use truck water combined with bottled water.

The postestimation analysis of the results of this MNL allows us to predict the probability of buying bottled water for each of those households.[10] This probability is a continuous variable between 0 and 1 and depends on a series of observable factors. We calculate two alternative predictions adjusting to zero (to the extent that we do have data about them from the survey) factors that may not be deemed related to water service quality issues (the indicators that the respondent suggested "water tastes better" or "we have a habit to buy bottled water" as reasons for purchasing bottled water). This results in an "adjusted" probability that could be used to down-weight the stated expense on bottled water, before we use that somewhat reduced expense to recalculate the affordability ratios. As explained in further detail in Appendix B.2, this results in a downward adjustment of the naive affordability ratios $AR2$ and $AR3$, making them fall more in line with potentially relevant normative judgments about the *need* versus the *want* of purchasing

[10]See Appendix B.

water from what is, in most cases, a much more expensive water source. Specifically, the first set of adjusted affordability ratios, $AR2_{nohabit}$ and $AR3_{nohabit}$, corrects for the bottled water expenses related to habit or habits. That is, we compute the predicted probability of buying bottled water setting *bottledhabit* to zero, and then we recalculate the corresponding affordability ratios. The second set of adjusted affordability ratios, $AR2_{allreasons}$ and $AR3_{allreasons}$, are adjusted in a similar manner, by accounting only for bottled water expenses that are unrelated to habits or to perceptions of taste and color and, as such, considered *legitimate* expenses on bottled water.

2.4 Modelling the drivers behind individual affordability measures

The next step in our analysis involves trying to find out which factors might help explain or identify the differences in the values of affordability ratios. As discussed in Section 3, we consider household characteristics and regulatory factors. The purpose of this exercise is not to identify causal relationships, but rather to understand the characteristics associated with affordability issues, so these can be taken into account by policymakers. Knowing what policy measures, in this case at the country level, contribute to higher levels of affordability ratios might be indeed directly useful for policymakers. But additionally, just knowing which factors correlate, even if without an identified causal effect, with issues of water affordability may also help those in charge of policies aimed at alleviating them. That is, factors behind the variability of affordability ratios that are not themselves policy variables can help regulators more finely target social policies (subsidies, rebates, income assistance, tariff design, etc.) by identifying what types of households are more prone to suffer lack of water affordability.

We use for this purpose Ordinary Least Squares (OLS) estimators and report inference indicators based on estimated standard errors that consider clustering by province, corrected with sampling weights to recover the representativeness of the sample, and follow appropriate combination rules (Rubin, 1987) of the imputed samples generated as part of our multiple imputation exercise.

3 Data and variables

This paper uses data from the 2021 wave of the AmericasBarometer of the LAPOP at Vanderbilt University. In partnership with LAPOP, the Water and Sanitation (WSA) Division of the Inter-

American Development Bank (IADB) designed a core questionnaire that included more than 20 questions focused on water and sanitation services.

While the AmericasBarometer usually collects data through face-to-face interviews, the outbreak of the coronavirus pandemic forced the team to administer the questionnaire using a randomized mobile phone and split-sample approach. Due to the high level of penetration of mobile phones in Latin America, the LAPOP team decided to design its sample using mobile phones rather than landlines. At the same time, due to the length of the complete questionnaire administered, the split sample approach allowed for doubling the number of respondents while shortening the amount of time each survey lasted. Finally, the data were also weighted to make sure that these results could also be compared across time with other samples from face-to-face interviews.[11] The countries considered in the analysis are Argentina, Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, and Uruguay.

As described in Section 1, the main variables considered to calculate an affordability ratio are the expenditure on water and income. The AmericasBarometer data include information on self-reported household water expenditure for piped, bottled and tanked water. It is important to note that the three water expenditure variables are not mutually exclusive, since a household can use a type of water source as primary water for either drinking and/or other water uses, and complement it with other water sources as needed. As explained in Section 2, we compute three affordability ratios based on differences in the water expenditure considered. The first ratio, $AR1$, is computed using expenditure on piped water (*expense piped*). In the second ratio, $AR2$, the water expenditure considered is the sum of expenditure on piped and bottled water (*expense piped & expense bottled)*. Last, the third ratio, $AR3$, is computed using the sum of expenditure on piped and bottled water, and water truck delivering service (*expense piped, expense bottled & expense truck*).

Household monthly income was recorded as an ordered categorical variable, because households were asked to choose among five income intervals. The intervals are country-specific, based on the quintile distribution of income in each country. Since the computation of affordability measures and regression analysis becomes challenging using a categorical income variable, we follow an imputation approach that simulates the distribution of the data reported in brackets, as described in Section 2.

[11] The reader is referred to the AmericasBarometer 2021 technical report for further information.

Once the affordability ratios are computed,[12] we analyze the characteristics associated with higher levels of water affordability issues. Among the variables considered in the analysis, we distinguish between household characteristics and regulatory factors. Household characteristics include socioeconomic and demographic variables, such as the number of people living in the house (*HHS*) and the proportion of children under 13 (*childrenratio*). We also consider two indicators of the education level of the head of the household, one that takes the value 1 if the education of the head of the household is higher than high school, 0 otherwise (*educmoreHS*), and another one that takes the value 1 if the education of the head of the household is lower than high school, 0 otherwise (*euclessHS*), leaving a high school education level as the reference category. In terms of the household's economic level, we include an indicator that the head of the household is employed (*employed*) and another one of whether the survey respondent reports having run out of food due to lack of money in the three months prior to the survey (*foodinsecure*). Last, we also include several variables that describe the access to water and sanitation in the house, such as the average number of daily hours of piped water service (*hoursofsupply*), and indicators of whether the household has access to piped water seven days a week (*supplycomplete*), whether sewage water is treated (*treatedsewage*), and whether the respondent lives in an urban area (*urban*).

In terms of regulatory factors, our study is guided by the research conducted by de Halleux et al. (2020). We explore the correlation between affordability and sectoral reform dimensions such as regulatory autonomy and experience. To accomplish this, we include two variables. Firstly, we consider one binary indicator (*IRA*), constructed using information from the UN-Water Global Analysis and Assessment of Sanitation and Drinking-water (GLAAS) 2021/2022 country survey, indicating that there exists an independent regulatory agency of the water sector in the country where the respondent lives, 0 otherwise. Secondly, we include a measure of the number of years since the HRTW was codified in the country's constitution or other legal frameworks (*HRTWyears*).

Table 1 includes summary measures of the variables used as independent variables in the regressions used to explain the values of affordability ratios or that inform their construction.

Finally, the variables used in the income imputation and the regression to adjust the affordability ratios for coping costs are described in Appendices A and B.1. In our analysis, these variables served the purpose of predicting income and water source consumption choice, but we are not

[12] And after removing from the sample observations which had resulted in affordability ratios in the upper 5% of the distribution, since we considered them outliers resulting from misrepresentation of one's income or misunderstanding of water expenditures.

Variable	Description	Mean	Std. Dev.	Min.	Max.	N
expense piped	Expense on piped water, monthly (USD PPP)	32.799	247.2	0	25403	22200
expense bottled	Expense on bottled (USD PPP)	21.771	72.32	0	4953	21703
expense truck	Expense on truck, monthly (USD PPP)	1.074	18.92	0	1808	21975
Income	Household income imputed (1000s/month USD PPP)	1.094	1.235	0.004	57.563	25735
childrenratio	Proportion of children in household	0.217	0.221	0	0.889	25486
HHS	Number of household members	4.183	2.166	1	25	25486
educlessHS	Education: less than High-School	0.181	0.385	0	1	25735
educmoreHS	Education: more than High-School	0.395	0.489	0	1	25735
employed	Respondent is employed	0.553	0.497	0	1	25735
hoursofsupply	Hours of water supply when available	20.295	7.361	0	24	25735
urban	Respondent lives in an urban area	0.566	0.496	0	1	25735
treatedsewage	Sewage goes to a treatment plant	0.073	0.26	0	1	25735
supplycomplete	Seven days/week of public water supply	0.832	0.374	0	1	25735
foodinsecure	Run out of food in the past 3 months	0.261	0.439	0	1	25735
IRA	Independent Regulatory Agency	0.822	0.383	0	1	25735
HRTWyears	Years country has had water human rights legislation	7.158	7.138	0	26	25735

Table 1: Summary descriptives of independent variables in regression models of affordability ratios.

interested in the specific estimated coefficients or infer causality from these regressions.

4 Results

4.1 Estimates of affordability ratios

We begin our analysis by calculating the naive measures of water affordability. That is, the basic water affordability ratio, $AR1$, and the ones that consider coping costs, $AR2$ and $AR3$. As explained in Section 2, $AR1$ is constructed as the ratio of the declared expense on piped water to monthly income; $AR2$ considers not only the declared expense on piped water but also the expense (without any adjustments) on bottled water; and $AR3$ also considers expenses on water purchased from trucks or street vendors. It is important to note that, for those households that declared no expenses on bottled water, we assumed the expense to be zero (so that household would not result in a missing case for the variable for the construction of the values of $AR2$ and $AR3$). This means that summary values (like those shown in Table 2) of the distributions of these ratios (means in particular) mask the fact that, for those households that do spend income on bottled water, the burden can be quite high.

Figure 1 shows a comparison of the mean of these three ratios by country. In general, the

Variable	Mean	Std. Dev.	Min.	Max.
AR1	0.03003	0.04826	0	0.17982
AR2	0.05758	0.07989	0	0.30149
AR3	0.0592	0.08256	0	0.31195
AR2$_{habit}$	0.05425	0.07709	0	0.29081
AR3$_{habit}$	0.05582	0.07966	0	0.30047
AR2$_{allreasons}$	0.05421	0.07705	0	0.29071
AR3$_{allreasons}$	0.05579	0.07963	0	0.30047
N		25,735		

Table 2: Descriptives of *adjusted* affordability ratios.

mean value of $AR1$ falls within comparable bounds in terms of previous studies. However, this comparison is not possible regarding $AR2$ and $AR3$. Colombia shows the highest $AR1$ (5.6%), which is in line with Cunial and Pérez-Urdiales (2024) who find that piped water is, on average, unaffordable for a basic level of water consumption. While this result may be surprising given the development of Colombia's water and sanitation sector and subsidy scheme López-Ruiz et al. (2024) compared to that of other countries in our sample, it is important to note that, while other countries such as Bolivia and Guatemala, charge higher prices (in PPP) for basic levels of water consumption (López-Ruiz et al., 2024), Colombia ranks among the LAC countries with higher access to piped water (Pérez-Urdiales and dos Santos, 2024). We observe a substantial increase in $AR2$ and $AR3$ with respect to $AR1$ for most countries, with the Dominican Republic showing the highest increase at 350% from $AR1$ to $AR2$. This country also has the smallest mean $AR1$ (1.2%); that is, water tariffs are quite low compared to income levels in the country. This specific example highlights the importance of including coping costs in the affordability analysis in developing countries where water tariffs may not be high but the presence of water service quality issues implies that households need to rely on more expensive alternatives.

The $AR2$ and $AR3$ take relatively similar values. Honduras, Guatemala, and Colombia have the highest mean value for these ratios, implying that households spend, on average, 9.2%. 7.9%, and 7.8%, respectively, when considering the three types of water sources. However, the potential explanation for this result may differ for these countries. Particularly, Honduras and Guatemala show a relatively low $AR1$, which means that piped water expenditures represent a lower proportion of household income when compared to other countries in the analysis, although this may be due to relatively low access to piped water. Moreover, survey respondents in Honduras and Guatemala declare that they receive piped water an average of around five days a week, for an average duration of about 12 hours a day in the month before the survey. Moreover, among those who report bottled water consumption, the main reason to choose this type of water alternative is water contamination, for more than 79% of the respondents in Guatemala and almost 72% of those in Honduras. In the case of Colombia, as seen above, piped water expenses, which are also included in the computation of $AR2$, represent a relatively high proportion of household income. Moreover, survey respondents indicate that they consume bottled water for reasons other than contamination, because of its better taste, color, availability or just out of habit (Pérez-Urdiales and dos Santos, 2024). That is, bottled water consumption may be due more to the households' preferences rather than their needs.

One last consideration regarding the $AR3$ is that the number of households in our sample that reported expenses on trucked water was very small. Therefore, the additional insights we obtained from our data from the constructions of $AR3$, relative to the analysis of $AR2$, are rather limited. Nevertheless, we include this analysis to highlight the differences across countries in terms of use of different water sources and as a guideline for other studies in developing countries, where the importance of expenses on water from trucks and street vendors can be much greater.

In line with the discussion in Section 1.4, we also report a comparison of the affordability ratios $AR1$, $AR2$, and $AR3$ by income quintile to better assess the extent of the presence of water affordability issues for the poorest quintiles of the income distribution. In particular, Table 3 shows the mean of the three affordability ratios by income quintile and country. We find that the affordability ratio decreases as income increases for all the analyzed cases. This result is particularly relevant for $AR1$, given that water and sanitation tariffs are largely subsidized in the LAC region. This may reflect the need for better subsidy targeting to benefit those in the lower quintiles of the income distribution.

All the affordability ratios exceed the common international standard of water expenses representing no more than 3% of household income for the lowest quintile, except for the Dominican Republic's $AR1$. This result indicates a general affordability problem for the poor in the countries considered in the analysis. Costa Rica shows the highest $AR1$ for the lowest quintile (9.5%). A possible explanation for this result is that, although Costa Rica is among the countries with the highest access to piped water in our sample according to the AmericasBarometer (Pérez-Urdiales and dos Santos, 2024), it also has a relatively high degree of income inequality (Stampini et al., 2023) and subsidies to piped water consumption may not be widely available, in spite of national

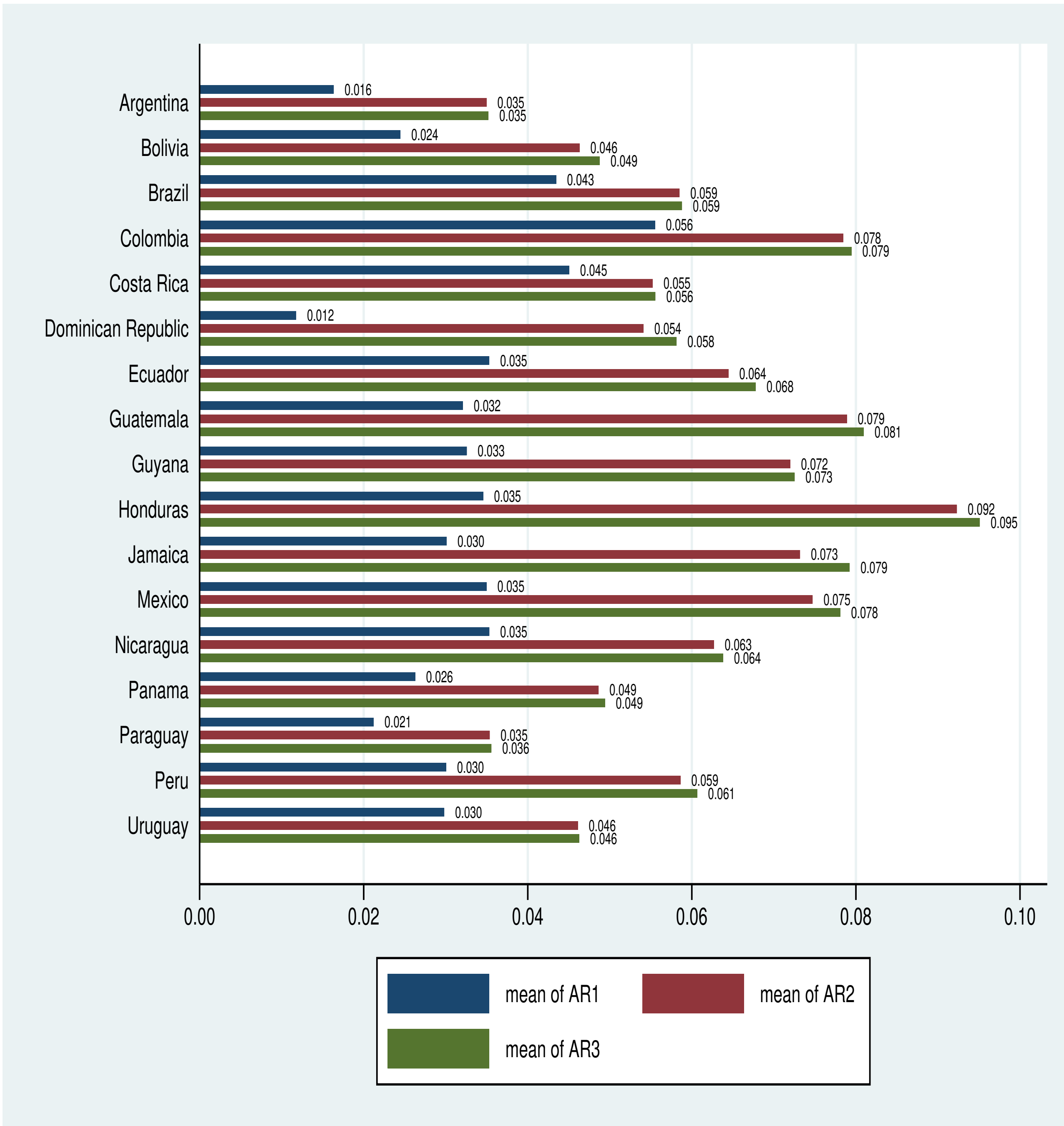

Figure 1: Mean of $AR1$, $AR2$ and $AR3$ by country

Country	AR1					AR2					AR3				
	Income Quintiles					Income Quintiles					Income Quintiles				
	Bottom	Second	Middle	Third	Top	Bottom	Second	Middle	Third	Top	Bottom	Second	Middle	Third	Top
Argentina	0.040	0.022	0.018	0.012	0.007	0.088	0.045	0.041	0.026	0.015	0.089	0.045	0.041	0.026	0.015
Bolivia	0.042	0.031	0.022	0.015	0.012	0.075	0.058	0.043	0.028	0.022	0.079	0.059	0.046	0.029	0.022
Brazil	0.067	0.054	0.040	0.029	0.019	0.102	0.074	0.054	0.038	0.026	0.103	0.074	0.054	0.038	0.026
Colombia	0.064	0.064	0.055	0.045	0.029	0.096	0.088	0.074	0.056	0.036	0.099	0.089	0.074	0.056	0.036
Costa Rica	0.095	0.061	0.040	0.027	0.013	0.124	0.073	0.046	0.032	0.016	0.125	0.073	0.046	0.032	0.016
Dominican Republic	0.027	0.011	0.008	0.007	0.003	0.114	0.062	0.043	0.030	0.015	0.120	0.069	0.046	0.030	0.016
Ecuador	0.057	0.039	0.030	0.021	0.009	0.120	0.065	0.051	0.034	0.014	0.126	0.067	0.054	0.035	0.014
Guatemala	0.047	0.031	0.016	0.016	0.006	0.116	0.071	0.045	0.037	0.015	0.119	0.072	0.047	0.037	0.016
Guyana	0.056	0.058	0.039	0.027	0.015	0.126	0.114	0.086	0.056	0.034	0.128	0.115	0.086	0.056	0.034
Honduras	0.054	0.029	0.020	0.012	0.009	0.134	0.082	0.056	0.031	0.021	0.140	0.084	0.059	0.032	0.022
Jamaica	0.035	0.034	0.036	0.025	0.015	0.104	0.082	0.071	0.050	0.026	0.112	0.087	0.077	0.055	0.028
Mexico	0.053	0.038	0.022	0.021	0.013	0.111	0.079	0.051	0.041	0.025	0.115	0.084	0.053	0.041	0.025
Nicaragua	0.053	0.039	0.029	0.017	0.006	0.093	0.066	0.048	0.032	0.016	0.095	0.067	0.048	0.032	0.016
Panama	0.050	0.032	0.026	0.018	0.010	0.090	0.062	0.048	0.031	0.020	0.093	0.062	0.048	0.031	0.020
Paraguay	0.036	0.025	0.021	0.014	0.011	0.060	0.043	0.036	0.028	0.020	0.061	0.043	0.036	0.028	0.020
Peru	0.038	0.030	0.032	0.025	0.012	0.077	0.059	0.058	0.044	0.023	0.081	0.061	0.058	0.044	0.023
Uruguay	0.076	0.056	0.037	0.023	0.010	0.108	0.085	0.056	0.038	0.019	0.109	0.086	0.056	0.038	0.019

Table 3: Affordability ratios by income quintile

efforts (López-Ruiz et al., 2024).

The affordability problem is exacerbated when coping costs are considered. Honduras, Guyana, and Costa Rica are the countries with the highest $AR2$ (and consequently, $AR3$ given that very few respondents report expenses on truck water) for the lowest quintile. A likely explanation for these relatively large portions of income spent on water is that, as survey respondents in these three countries indicate, their main reason for consuming bottled water is to avoid water contamination.

Looking at the top quintile, the international standard threshold is not exceeded by any country for $AR1$, and it is only slightly higher than 3% in Colombia and Guyana when measured by $AR2$ and $AR3$, possibly due to bottled water consumption.

To further describe the disparities in affordability, we show in Table 4 the ratios in each country of the mean of each type of affordability ratio between the bottom quintile and the top quintile. We observe that the countries with the highest disparity in $AR1$ are the Dominican Republic, Guatemala, and Nicaragua, whereas the highest dispersion in $AR2$ and $AR3$ is found in the Dominican Republic, Ecuador, and Guatemala. While exploring the sources of these disparities is out of the scope of this study, they could be related to income inequalities, inadequate water tariff designs, or the disproportionate impact of water service quality problems on the poor.

Table 5 shows the results of testing the mean differences of the variables that measure each of the three types of ratios. We can see that there are significant differences (at the 1% significance level) between the different ratios, with the exception of $AR2$ adjusted for habit versus $AR2$ adjusted for all reasons. However, it is important to note that the differences between the means are approximately zero across comparisons, and the level of significance may be largely driven by the large sample size.

4.2 Understanding differences in affordability

Tables 6 and 7 show the estimation results identifying the factors associated with the different affordability ratios. Specifically, Table 6 shows the regression results of the affordability ratios $AR1$, $AR2$, $AR3$, $AR2_{allreasons}$ and $AR3_{allreasons}$ on household characteristics and country indicators (except for the indicator for Argentina, which is excluded to avoid perfect multicollinearity and it is, therefore, the reference country), and Table 7 presents the regressions of the same set of dependent variables on household characteristics and regulatory variables. That is, we first present the results

	$\frac{AR1_{bottomquintile}}{AR1_{topquintile}}$	$\frac{AR2_{bottomquintile}}{AR2_{topquintile}}$	$\frac{AR3_{bottomquintile}}{AR3_{topquintile}}$
Argentina	5.149	6.077	6.164
Bolivia	3.625	3.818	4.049
Brazil	3.745	3.974	4.007
Colombia	1.905	2.429	2.485
Costa Rica	7.193	7.585	7.671
Dominican Republic	9.576	8.518	8.247
Ecuador	6.556	8.234	8.541
Guatemala	7.878	7.755	7.933
Guyana	3.494	3.546	3.607
Honduras	7.18	6.21	6.327
Jamaica	2.209	3.963	3.844
Mexico	3.97	4.475	4.612
Nicaragua	7.873	4.634	4.768
Panama	5.484	4.897	5.059
Paraguay	3.307	2.976	3.006
Peru	3.557	3.689	3.813
Uruguay	5.773	4.785	4.853

Table 4: Ratios of mean AR for bottom quintile to mean AR for top quintile of income distribution

Comparison	$AR2$ $vs.$ $AR2_{habit}$	$AR2_{habit}$ $vs.$ $AR2_{allreasons}$	$AR3$ $vs.$ $AR3_{habit}$	$AR3_{habit}$ $vs.$ $AR3_{allreasons}$
mean	0.0034	0.0000	0.0034	0.0000
pvalue	0.0000	0.0777	0.0000	0.0096

Table 5: Tests of means to compare affordability ratio measures.

	AR1	AR2	AR3	$AR2_{allreasons}$	$AR3_{allreasons}$
childrenratio	0.0034	0.0090***	0.0110***	0.0089***	0.0109***
HHS	0.0007***	0.0016***	0.0016***	0.0015***	0.0016***
edulessthanHS	0.0020*	0.0003	0.0003	-0.0001	-0.0000
edumorethanHS	-0.0065***	-0.0106***	-0.0115***	-0.0099***	-0.0107***
employed	-0.0042***	-0.0061***	-0.0063***	-0.0061***	-0.0063***
hoursofsupply	-0.0007***	-0.0009***	-0.0008***	-0.0009***	-0.0008***
urban	0.0093***	0.0090***	0.0097***	0.0085***	0.0092***
treatedsewage	0.0047**	-0.0008	-0.0014	0.0002	-0.0004
supplycomplete	-0.0108***	-0.0132***	-0.0118***	-0.0128***	-0.0114***
foodinsecure	0.0069***	0.0148***	0.0155***	0.0140***	0.0147***
Bolivia	0.0061	0.0062	0.0083	0.0060	0.0080
Brazil	0.0237***	0.0207***	0.0208***	0.0197***	0.0197***
Colombia	0.0362***	0.0381***	0.0389***	0.0376***	0.0384***
CostaRica	0.0307***	0.0221***	0.0223***	0.0220***	0.0222***
DominicanRepublic	-0.0118***	0.0095*	0.0142**	0.0078	0.0125**
Ecuador	0.0156***	0.0234***	0.0263***	0.0219***	0.0248***
Guatemala	0.0101***	0.0344***	0.0369***	0.0313***	0.0337***
Guyana	0.0196***	0.0395***	0.0402***	0.0302***	0.0308***
Honduras	0.0084**	0.0418***	0.0446***	0.0398***	0.0426***
Jamaica	0.0153***	0.0371***	0.0435***	0.0311***	0.0373***
Mexico	0.0127***	0.0334***	0.0371***	0.0295***	0.0331***
Nicaragua	0.0099***	0.0142***	0.0157***	0.0146***	0.0161***
Panama	0.0085***	0.0100***	0.0109***	0.0086**	0.0095**
Paraguay	0.0047	-0.0012	-0.0014	-0.0020	-0.0022
Peru	0.0122***	0.0232***	0.0256***	0.0213***	0.0235***
Uruguay	0.0151***	0.0145**	0.0144**	0.0145**	0.0144**
constant	0.0354***	0.0565***	0.0530***	0.0551***	0.0517***
N	25,418	25,418	25,418	25,418	25,418

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: OLS regressions of *AR1*, *AR2*, and *AR3*, as well as of $AR2_{allreasons}$ and $AR3_{allreasons}$

	AR1	AR2	AR3	$AR2_{allreasons}$	$AR3_{allreasons}$
childrenratio	0.0018	0.0082**	0.0101***	0.0082**	0.0100***
HHS	0.0006***	0.0018***	0.0019***	0.0017***	0.0018***
edulessthanHS	0.0019	0.0012	0.0010	0.0011	0.0009
edumorethanHS	-0.0071***	-0.0113***	-0.0121***	-0.0104***	-0.0112***
employed	-0.0044***	-0.0056***	-0.0057***	-0.0058***	-0.0060***
hoursofsupply	-0.0007***	-0.0010***	-0.0010***	-0.0010***	-0.0009***
urban	0.0101***	0.0064***	0.0066***	0.0067***	0.0068***
treatedsewage	0.0054***	-0.0008	-0.0015	0.0008	0.0001
supplycomplete	-0.0088***	-0.0144***	-0.0136***	-0.0140***	-0.0132***
foodinsecure	0.0072***	0.0154***	0.0165***	0.0151***	0.0162***
IRA	0.0125***	0.0055	0.0041	0.0055	0.0040
HRTWyears	-0.0005***	-0.0008***	-0.0008***	-0.0007***	-0.0007***
constant	0.0388***	0.0829***	0.0834***	0.0782***	0.0787***
N	25,418	25,418	25,418	25,418	25,418

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: OLS regressions of *AR1*, *AR2*, and *AR3*, as well as of $AR2_{allreasons}$ and $AR3_{allreasons}$. No country indicators

for the basic affordability ratio, $AR1$ (Column 1), next the ratios also including bottled water, $AR2$, (Column 2) and all water expenses, $AR3$ (Column 3), and then the second and third ratios after adjusting them by normative judgements about the need for coping strategies, $AR2_{allreasons}$ and $AR3_{allreasons}$ (Columns 4 and 5).

The intercepts in Table 6 represent the mean affordability ratio for Argentina (reference country) when all the other explanatory variables are equal to 0. For the remaining countries, the mean affordability ratio is computed as the sum of the intercept and the corresponding coefficient of the country indicator. The results, in line with those presented in the previous section, show that, in general, the affordability ratio takes higher values as the ratio also considers more coping strategies. Moreover, the results remain mostly unchanged when we adjust for normative judgements.

Regarding household characteristics, *childrenratio* has a positive coefficient for all the estimated models. That is, the higher the proportion of children over the total number of people living in the house, the higher the share of water expenses over income. The coefficient is, however, much higher and indeed statistically significant, in the cases when the affordability ratio accounts for expenses on bottled water. The effect is weaker and not statistically significant on $AR1$. These results may be explained by the concern of parents over contamination of their children's drinking water.[13] Indeed, many studies (March et al., 2020; Dupont et al., 2010; Rosinger and Young, 2020) find that the presence of children in the household is a key determinant of tap water avoidance and reliance on bottled water. The number of children in the household has been found associated with higher water insecurity metrics (Martins et al., 2016; Rosinger and Young, 2020; Stoler et al., 2020).

The coefficient for *HHS* is also positive and significant across estimations. That is, larger households tend to be associated with higher levels of affordability ratios, even after the number of children is controlled for. Moreover, this relationship is more than twice as strong when we consider more expensive alternatives, such as bottled water. Household size has been found a determinant of the choice to purify tap water (Johnstone and Serret, 2012), so it might partly explain the reliance on the alternative, and more expensive water sources, even after controlling for the presence of children in the household. Additionally, under increasing block water tariffs, given that household size economies of scale are exhausted relatively soon (Dahan and Nisan, 2007), larger households

[13]Some studies show an effect of children on water purification practices but not on bottled water consumption (Johnstone and Serret, 2012), which suggest that health concerns are what drive the effect of the presence of children on bottled water purchases.

(to the extent that their income is less than proportional to size and that larger households are also often poorer) would naturally be relatively more impacted by water expenses. In fact, this is one of the often-mentioned unintended equity effects of increasing block tariffs (Pierce et al., 2021). In our analysis, we observe it through the association between household size and all three types of affordability ratios that we calculated.

The coefficients for *edumorethanHS* and *employed* are negative and significant across all the estimated models. This implies that we observe lower affordability ratios if the head of the household has reached an education level higher than high school or if this person is employed, with stronger associations when we consider coping costs. Since these variables are closely related to the household's socioeconomic status, they may reflect a higher level of wealth or access to capital (since income is controlled for in our model) but also less exposure to water service quality issues. The negative association between education (especially postsecondary education, which is what our variable *edumorethanHS* measures) and bottled water consumption has been documented in the literature (Pierce and Gonzalez, 2017; Rosinger et al., 2018; Rosinger and Young, 2020). This would partly explain the stronger effect of education on the size of affordability ratios $AR2$ and $AR3$, both of which account for expenses on bottled water.

Last, reporting having run out of food in the three months before participating in the survey due to lack of money is associated with higher affordability ratios. In particular, the share of income devoted to piped water expenses is almost 0.7 percent points higher for households experiencing food security issues. This magnitude doubles when we also consider expenditures on bottled water and truck deliveries. This is a result that agrees with previous research (Stoler et al., 2020): not surprisingly the issues of water insecurity and food insecurity go hand-in-hand for most households and should be addressed jointly by policymakers.

Households living in urban areas tend to spend a higher proportion of their income on water, a result that agrees with the findings of earlier works, such as Shah et al. (2023), although Stoler et al. (2020) found that rural households faced higher water insecurity score. This result may be because, although rural areas tend to have less complete water supply coverage (Cook et al., 2016; Stoler et al., 2020), urban water utilities usually provide a better supply service, resulting in higher prices. As noted by Jepson et al. (2021), there is limited extant research on the differences between rural and urban water users when it comes to water affordability. However, although urban households are normally expected to enjoy better access to water and more reliable aggregate supply systems, because of the better supply infrastructure in cities, there is some recent evidence to suggest that water security is not always guaranteed for all urban dwellers. Additionally, although they might pay higher fees, because they do have access to developed supply systems, households in smaller cities might be more vulnerable to supply issues during droughts and they also have less access to alternative water sources (Jepson et al., 2021). Rural households have access to many alternative water sources but many do not entail the financial costs that our affordability measures considered.

After controlling for rural versus urban location, we found that households with more hours of supply per day and service seven days a week show lower values of the affordability ratios. A possible explanation for this result is that households with recurrent service interruptions need to store water when the service is available, which may cause wasteful consumption, as well as having to resort to expensive short-run coping measures based on more expensive sources than tap water. The coefficients associated with *hoursofsupply* and *supplycomplete* are more negative when we consider coping costs, as these water service problems may cause consumers to rely more on alternative and more expensive sources, resulting in a higher share of water expenses over income. Last, treated sewage results in a higher portion of income spent on piped water, as prices may be higher in jurisdictions with more complete water supply systems, but not on alternative sources of water, so we find a positive effect on $AR1$ and a negative effect, if not statistically significant, on the more comprehensive affordability ratios. We do not observe substantial differences between the results of the naive affordability ratios and those adjusting for non-essential uses.

As noted above, in Table 7 we show the results that include regulatory variables. Due to multicollinearity issues, we do not include country indicator variables in these estimations. The results remain generally unchanged in terms of household characteristics.

In terms of the regulatory variables, we observe that the existence of an independent regulatory agency in the country is positively correlated with a higher share of income spent on piped water, but the relationship is not significant when we include the other water expenses. This result may be due to the stringent regulation imposed by this type of agencies, which results in a better service but higher piped water prices. That is, while piped water is more expensive, there is no need for coping strategies.

As expected, households in countries where the HRTW is codified in the Constitution experience fewer water affordability issues.

5 Policy discussion

Measuring water affordability is fundamental for understanding the effort needed to achieve universal access to water services as part of the 2030 Agenda. This is especially crucial in developing countries, where households may need to rely on multiple water sources, which may result in substantial water expenses. Moreover, identifying the factors associated with lower affordability levels can help better target policies aiming at ensuring affordable access to water. The results of this regional study show general affordability issues for low-income families across LAC. While this problem becomes more profound as we consider several water sources in the construction of the water affordability ratio, it is already present when we only account for piped water services. Given that the higher the income, the lower the presence of water affordability problems and that the water and sanitation sector is heavily subsidized in the region, subsidy targeting may need to be reconsidered across all countries included in this study.

As mentioned before, the problem is worse when expenses on alternative water sources, such as bottled water or truck water, are included in the construction of the water affordability ratio. However, following a reasonable normative approach and since consumption of alternative water sources may be driven by household preferences and habits, we compute a set of adjusted water affordability ratios that correct for expenses related to habits or preferences. These ratios, though, do not strongly differ from the naive water affordability ratios that consider all bottled water consumption as necessary because of quality inadequacies in the supply of tap water. Therefore, given that water expenses still represent a portion of household income higher than the international standard threshold for a large share of the households in the study, it is important to improve water service quality across the region to ensure affordability.

Although our contribution is relatively limited when it comes to the study of policy variables (whether at the national or the local level), we expect that the results of our analysis will help policymakers identify the households more likely to face water affordability issues. Better knowledge of factors that correlate, even if without an identified causal effect, with water affordability issues may thus help those in charge of policies aimed at alleviating water insecurity by more finely targeting poverty alleviation measures (subsidies, rebates, income assistance, tariff design, etc.).

In sum, our findings can be useful in creating fair water pricing systems that balance the need for additional funding to maintain and expand water supply services, while also ensuring that low-income households can access these services at reasonable rates.

Our research agrees with earlier works that lower-income households often have inadequate coverage of Water, Sanitation, and Hygiene (WASH) services. Therefore, policies aimed at water poverty alleviation must prioritize poor and marginalized population groups (Hutton and Varughese, 2016). However, these policies must also balance the need for basic access for the currently uncovered households while providing enhanced services to households who currently enjoy access to those basic services (Hutton and Varughese, 2016). This consideration is particularly relevant given that a substantial portion of water affordability issues are often related to expenses on water sources other than formally supplied piped water, as confirmed by our results. Therefore, research efforts should aim to develop a more nuanced understanding of the affordability challenges faced by underserved populations in Low and Middle Income Countries (LMICs). This understanding will help design policy responses that best cater to the needs of particular communities (Patterson and Doyle, 2021).

Our findings confirm the previous research by, for instance, Rosinger et al. (2023) that highlights the connection between access to good quality tap water and food insecurity. Both issues have been increasing over time, which is why it is important to address water insecurity along with food insecurity. Households that lack access to safe tap water are more likely to suffer from food insecurity because they cannot afford to cook healthy meals and because the relatively high water expenses leave them even more vulnerable to food insecurity. Interventions that increase household expenditures on water without anti-poverty and income generation measures may worsen water insecurity, especially for low-income households Stoler et al. (2020). Therefore, it is crucial to tackle both water and food insecurities simultaneously.

6 Conclusions

Water affordability measures focusing on expenses associated with piped water consumption may underestimate affordability issues in the presence of service quality problems, which are common in developing countries. In this paper, we compute and compare different measures of water affordability based on various water sources reported by a sample of households from 18 countries in LAC.

Our results show a substantial increase in the share of income devoted to water expenditures when we move from an indicator that only considers expenses on piped water to indicators that also consider coping costs. When we focus on the bottom 20% of the income distribution, most of the affordability ratios considered exceed the common international standard of water expenditure being no higher than 3% of household income. Furthermore, this situation worsens when we also account for coping costs.

Our data set included not only information about the different types of water sources households used but also about the reasons why they used them. This made it possible for us to illustrate the construction of affordability ratios that adjust downward household expenditures on relatively expensive water sources to an extent proportional to the effect on the probability that each household chose those sources for reasons that might not be deemed legitimate from a normative point of view.

In our study, we experimented with the adjustment of the expenditure on bottled water for reasons related merely to habits or perceptions of colour and taste (as opposed to objective measures quality of the piped water). We used the predictions obtained from a multinomial logit model to adjust the expenditures on bottled water reported by the households. In our case, the effect of this correction was relatively small. However, it is important to note that the quantitative effect of this type of correction is affected by the number and type of variables included in the specification of the multinomial logit model, as well as their specific effect within a given jurisdiction. Further work might reveal that the choices of water sources are affected by variables for which we did not have information in our sample. The effect of the correction is also informed by the specific magnitude of the expenditure adjustment one chooses to link to differentials in predicted probability. This magnitude involves a normative choice, itself linked to the extent to which the calculation of affordability ratios is based on the notion of *needs* versus *wants*.

In this sense, our strategy is relatively *ad hoc* but it constitutes a way to systematically account for different reasons why households purchase bottled water, some of which might not be considered essential, while at the same time allowing for differential treatment of the expenses of each individual household. Although there is an element of arbitrariness in the magnitude of this adjustment, once the factor affecting the choice of water sources is identified from a normative perspective, the adjustment of the affordability ratio would follow an objective criterion across households. Of course, another limitation of our approach in practice is that it requires information to estimate the MNL in the first place. That is, regulators would need access to information on the reasons why households choose alternative sources of water supply to be able to tease out the portion of the expenditure that constitutes a legitimate coping cost.

In practice, we acknowledge that this approach would likely only represent a first-order approximation to the task of constructing a more fair indicator of water affordability, which would only apportion costs related to *needs* to the measure of affordability, than the basic water affordability ratios based on explicit costs difference sources of water supply.

Moreover, we also identify the characteristics associated with greater shares of income spent on total water consumption. Larger households, those with a greater proportion of children, and those whose head is less educated and not employed are at higher risk of experiencing affordability issues, especially when coping costs are included in the computation of their affordability ratio. Moreover, households who experienced food insecurity in the three months before participating in the survey are more likely to also experience affordability issues, highlighting the multidimensional complexity of poverty and affordability issues.

In terms of regulation, we observe that the existence of an independent regulatory agency in the country is associated with higher shares of income spent on piped water, but the relationship is not significant when we consider coping costs. This implies that tighter regulation may result in higher water tariffs but also better water service quality, which prevents the need for households to devote high shares of income to alternative water sources. Last, the number of years after a country codifies the HRTW in their constitution is associated with lower levels of the water affordability ratios. That is, not only is it important for countries to codify this human right, as it recognizes the importance of the affordability of safe water but it may also require time to exert a greater impact.

From a policy point of view, our results highlight the importance of effecting stringent regulations to reduce water affordability problems. In line with this, the recognition of water as a human right implies certain obligations for the countries that result in lower shares of income devoted to water expenditure on multiple sources.

Several actions could be taken to ensure access to affordable water, as suggested elsewhere (e.g. Revollo-Fernández and Rodríguez-Tapia, 2021). These include improving the design of subsidies for domestic water use, easing the burden on smaller consumers, and supporting programs aimed at fostering economic efficiency while reducing consumption. To reduce poverty, aid could be increased for disadvantaged households, and assistance could be provided for leak repairs and installation of efficient retrofits. Users could also be helped to access existing social support programs to assist with paying their water bills. All these targeted measures to aid low-income households and providing specific assistance can be effective. However, water supply services must remain financially balanced. One option that has been used, particularly in combination with increasing block pricing, is to supply a fixed water amount per household (or person) at a low cost.

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Appendix A Summary descriptives of variables used in income imputation

Variable	Description	Mean	Std. Dev.	Min.	Max.
educlessHS	Education: less than High-School	0.181	0.385	0	1
educmoreHS	Education: more than High-School	0.395	0.489	0	1
childrenunder13	Number of children under 13 in the household	1.07	1.271	0	16
phone	Landline phone	0.275	0.447	0	1
washer	Washer in home	0.635	0.482	0	1
microwave	Microwave in home	0.415	0.493	0	1
computer	Computer in home	0.508	0.5	0	1
internet	Internet supply contract at home	0.544	0.498	0	1
TV	Flatscreen TV at home	0.682	0.466	0	1
cableTV	Cable/Satelite TV at home	0.51	0.5	0	1
	N=25,735				

Table 8: Summary descriptives of variables used in income imputation

Appendix B Prediction of probabilities of choosing among drinking water sources

B.1 Estimation of households' choice of water source

Table 9 shows the distribution of *water_source*, which was used to explain the choices of households about water source using a MNL model. From the results of this MNL model, we can calculate the individual predicted probabilities that households consume water from a certain combination of sources. We are interested in describing the model's predictions by the stated reasons to purchase bottled water, in order to be able to adjust the affordability ratio to account for the fact that some expenditure in bottled water might be reasonably deemed nonessential and thus not belonging in the calculation of a measure of the burden of expenses on water.

Formally, the MNL model of water source choice is expressed as:

$$Prob(water\ source_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{k=0}^{J} e^{\beta'_k x_i}} \quad j = 0, ..., J \tag{16}$$

where j represents the different outcomes *Piped*, *Bottled*, *Truck_or_Truck_and_Bottled* and *Piped_and_Bottled* for household i, x_i is a vector of household characteristics and βj is a vector of parameters to estimate for each of the j outcomes. The resulting estimated equations generate a set of probabilities for the household choice of water source.

As noted by (Greene, 2000, p. 860), the estimation of the MNL model is by maximum likelihood, with the log-likelihood derived by defining $d_{ij} = 1$ if water source j is chosen by household i, and 0 otherwise:

	freq	pct	cumpct
Piped	4821	29.65	29.65
Bottled	3739	23.00	52.65
Truck_or_Truck_and_Bottled	248	1.53	54.18
Piped_and_Bottled	7450	45.82	100.00
Total	16258	100.00	

Table 9: Distribution of observations by *water_source*

$$lnL = \sum_{i=0}^{n} \sum_{j=0}^{J} d_{ij} lnProb(water\ source = j) \tag{17}$$

The explanatory variables used in the MNL estimation are presented in Table 10.

The values of all x_i variables in the model affect the probability of adopting each combination of water sources. Since x_i can contain actual values obtained from the households in the sample or hypothetical values, we can the predict probabilities that a household chooses a certain combination of water sources both under current circumstances but can also simulate probabilities under alternative, hypothetical, conditions.

Variable	**Description**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
bottledtaste	Reason for drinking bottled water is taste-related	0.017	0.129	0	1	25735
bottledcolor	Reason for drinking bottled water is color-related	0.002	0.041	0	1	25735
bottledhabit	Reason for drinking bottled water is habit-related	0.013	0.115	0	1	25735
supplycomplete	7 days/week water service	0.561	0.496	0	1	24738
supplycompleteday	24 hours of water service	0.495	0.5	0	1	24198
improved	Access to an improved water source	0.913	0.282	0	1	25296
HHS	Number of household members	4.183	2.166	1	25	25486
Income	Household income imputed, 1000s/month USD PPP	1.094	1.235	0.004	57.563	25735
bathroom	Bathroom in the home	0.984	0.124	0	1	25604
washer	Washer in home	0.635	0.482	0	1	25735
fridge	Fridge in home	0.853	0.354	0	1	25735
internet	Internet supply contract at home	0.544	0.498	0	1	25735
internetaccess	Internet access at home	0.814	0.389	0	1	25735
employed	Respondent is employed	0.553	0.497	0	1	25735
urban	Respondent lives in an urban area	0.566	0.496	0	1	25735
childrenratio	Proportion of children in household	0.217	0.221	0	0.889	25486
edumorethanHS	Education: more than High-School	0.395	0.489	0	1	25735
edulessthanHS	Education: less than High-School	0.181	0.385	0	1	25735
treatedsewage	Sewage goes to a treatment plant	0.073	0.26	0	1	25735

Table 10: Summary descriptives of variables used in multinomial logit estimation of the choice of water source.

B.2 Calculation of *adjusted* affordability ratios to correct for *nonessential* uses

After estimating the MNL model, we calculate predictive margins (also known as recycled predictions), to vary the values of indicators such as *bottledhabit* across the whole dataset and then average the predictions. That is, we have data on both households who state that they buy bottled water (partly or wholly) out of habit (*bottledhabit*=1) and households who do not (*bottledhabit*=0). All of our individual households also have a combination each of values of all other variables.

We first simulate that, for all households in our sample, *bottledhabit* equals 1, while holding all their other characteristics as they are. We then proceed to calculate the predicted probabilities of each water source combination ("Piped only", "Bottled", "Truck or truck and bottled", and "Piped and bottled"). Next, we simulate instead that, for all households, *bottledhabit* equals 0, still holding their other characteristics constant. The recalculated probabilities of each combination include now only motives normatively deemed to justify a "need" to purchase bottled water, rather than a "preference". The difference between those two predicted probabilities is then used to adjust downwards the components of the total expense on water that builds the numerator of the affordability ratios that are due to *expensebottledppp*. In some cases, that is all that builds the numerator of the ratios, in some other cases, a piped water component is there but our adjustment strategy should only affect the component due to purchases of bottled water.

We then compare predicted probabilities associated with having (as some households originally did have, while for others we artificially assigned for the purpose of this calculation) chosen to buy bottled water because of habit (*bottledhabit* equals 1) predicted probabilities associated with not having stated that reason (*bottledhabit* is 0), either because the household never did originally or because we artificially assigned that zero.

Not having the habit of buying bottled water affects the predicted probability of buying bottled water, either by itself or in combination with piped water. The only three combinations considered in our adjustment exercise are the ones that involve piped water and bottled water. This is because they are the only ones we need, being the only ones for which an adjustment of the affordability ratio would be needed. We do not have any reason to water down the expenses on trucked water. However, the predicted probabilities of buying trucked water would also be altered (if in a way that we do not need to track for the purpose of adjusting the affordability ratios) as we change the

	Multinomial Logit, versus Piped		
	Bottled	Truck or Truck&Bottled	Piped&Bottled
botttaste	1.9642***	1.5845**	1.8139***
bottcolor	0.8620	-16.0914***	0.9761*
botthabit	1.7269***	1.7245***	1.3215***
sevendays_serv	-2.4368***	-18.2681***	-0.2654***
hours_serv	-1.6729***	-17.3332***	-0.4273***
improved	-1.3264***	-0.6570**	-0.9664***
HHS	-0.0506***	-0.0576	-0.0213
newincome	0.2415***	-0.2023	0.1672***
bathroom	-0.1649	-0.5461	0.4909*
washer	0.3560***	0.0467	0.2295**
fridge	-0.0036	0.2961	0.3920***
internetcontract	0.1930*	0.0756	0.1897**
internetaccess	0.4219***	0.3179*	0.5081***
employed	0.1830**	0.0294	0.2476***
urban	-0.2939***	0.1905	0.0154
childrenratio	-0.0682	0.4434	0.0590
edumorethanHS	-0.1368	-0.4109*	-0.0004
edulessthanHS	0.2435***	-0.1458	0.0907
treatedsewage	-0.3811**	-0.8056	-0.1025
constant	2.2892***	-0.0993	-0.0184
N	14711		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Multinomial logit of recombined types of water source

values of any variable, like *bottledhabit* in this case.

Note that the effect of changing *bottledhabit* from 1 to 0 on the predicted probability varies among households, so the adjustment of their affordability ratio will be individualized.[14] Note also that the predicted probability of buying bottled water *only* might not always decrease. It might be that what decreases is only the predicted probability of buying it *together with piped water*. Because our adjustment will be working through the expenses on bottled water for both those who only say to pay for bottled water and those who also pay for piped water, the adjustment strategy is still appropriate in any case. In sum, we can illustrate the construction of the adjusted affordabilitiy ratios by showing the example of $AR2_{habit}$, which can would be constructed as follows:

$$AR2_{habit,i} = \frac{expense\ piped_i + expense\ bottled_i[1 - bottledhabit \cdot \Delta_{bottledhabit=1\to 0}(\widehat{Prob}(Bottled))]}{income \cdot 1000} \tag{18}$$

The construction of the adjusted $AR3$ would add *expensetruck*, never adjusted (since we assume that only *legitimate* reasons prompt consumers to purchase water from a truck) to the numerator of Equation 18. The calculation of $AR2_{allreasons}$ and $AR3_{allreasons}$ would simply extend Equation 18 by including also *bottledtaste* and *bottlecolor* where Equation 18 reads *bottledhabit*.

[14]This is because the nonlinear nature of the MNL model implies that the effect of any variable, like in this case the effect of *bottledhabit* is not constant but rather depends onth evalues of al other independent variables.