WORKING PAPER Nº IDB-WP-01657

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November 2024

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Perez-Urdiales, María.
Water expenditure, service quality and inequality in Latin America and the Caribbean / María Perez-Urdiales, Carolina Tojal Ramos dos Santos.
p. cm. — (IDB Working Paper Series; 1657)
Includes bibliographic references.
1. Water security-Tariff-Latin America. II. Water security-Tariff-Caribbean Area. 3. Water security-Subsidies-Latin America. 4. Water security-Subsidies-Caribbean Area. 5. Equality-Latin America. 6. Equality-Caribbean Area. 7. Sustainable development-Latin America. 8. Sustainable development-Caribbean Area. I. Tojal, Carolina. II. Inter-American Development Bank. Water and Sanitation Division. III. Title. IV. Series.
IDB-WP-1657

http://www.iadb.org

Water Expenditure, Service Quality and Inequality in Latin America and the Caribbean

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Abstract

Latin America and the Caribbean (LAC) countries have made notable progress in reducing income inequality; however, the extent to which water and sanitation may foster inequalities remains unclear. In this sector, disparities emerge as lower-income households may encounter reduced access to clean water, utilize less water, or bear a disproportionately higher financial burden than higher-income households. In this paper, we investigate latter source of inequality in the water and sanitation sector in LAC. We analyze and compare inequality measures for water expenditures and income for Brazil, Colombia, Costa Rica, and Uruguay using survey data from the Americas Barometer of the Latin American Opinion Project (LAPOP). Our descriptive analysis indicates that low-income households allocate a larger proportion of their income to water expenditures compared to high-income households. By comparing the water concentration curve to the Lorenz curve for each country, we find that water expenditures are generally more equitably distributed than income, leading to an unequalizing effect, as households spend similar amounts regardless of income level. Additionally, we demonstrate that total water expenditures, encompassing tap water, bottled water, and water delivered by trucks, align more closely with income distribution than tap water alone in Brazil, Costa Rica, and Uruguay, whereas the opposite is true for Colombia. These disparities may be attributed to water tariff subsidies and the higher consumption of bottled water among wealthier households.

Keywords: water expenditures, water quality issues, inequalities, water inequalities, Latin America and the Caribbean

JEL codes: Q21, O13, O54, Q25

1 Introduction

In recent decades, Latin America and the Caribbean (LAC) have made impressive economic, social, and environmental progress. However, considerable effort is still required to achieve the Sustainable Development Goals (SDGs). For instance, while income inequalities have been substantially reduced across the region, they are still high compared to other countries with a similar level of development (López-Marmolejo et al., 2020). Substantial progress has also been made in the water and sanitation sector, where the share of the population with access to improved water services is around 90% in urban areas (Vidal et al., 2021). Nevertheless, disparities persist, particularly affecting lower-income households with reduced access, service quality problems, and higher shares of income dedicated to water expenditures, potentially contributing to fostering inequalities.

This paper investigates whether water expenditures contribute to inequality in LAC countries. To do so, we analyze and compare inequality measures for water expenditure and income for Brazil, Colombia, Costa Rica, and Uruguay. We consider that household water expenditure in the region includes the cost of tap water and expenditures associated with alternative sources, such as bottled water or water delivered by trucks. These alternative sources are often used due to accessibility and reliability problems with water services, which may be more frequent in low-income communities. Therefore, we assess inequalities in tap and total water expenditures, encompassing tap, bottled, and truck water delivery. In this context, this investigation aligns with the United Nations Sustainable Development Goals (SDGs) #6, "ensure availability and sustainable management of water and sanitation for all", precisely target 6.1 "by 2030, achieve universal and equitable access to safe and affordable drinking water for all", and #10, "reduce inequality within and among countries", to describe their current regional state and the interconnection between these two goals.

We use survey data from the Americas Barometer of the Latin American Opinion Project (LAPOP) to compute concentration measures for income and water expenditures for the analysed countries. We begin with a descriptive analysis, examining the distribution of water access, income, and water expenditures across countries. Subsequently, we graph the concentration curves to compare income and water expense distributions within each country. Lastly, we calculate the Kakwani index, a redistribution measure, to assess the regressive nature of water expenditures across countries.

We show that low-income households spend a larger share of their income on water than high-income households. Our results underscore that water expenditures are generally more equally distributed than income, resulting in an unequalizing effect, as households spend a similar amount regardless of income level. Looking at the different sources, we find that total water expenditures, including tap water, bottled water, and water delivered by trunks, are distributed more similarly to income than tap water alone for Brazil, Costa Rica, and Uruguay. In contrast, we find the opposite for Colombia. We discuss that these differences may be attributed to water tariff subsidies and the prevalence of bottled water consumption among higher-income households.

This paper contributes to discussions on the relationship between SDGs #6 and #10, as the first SDGs report on the progress on drinking water, sanitation, and hygiene (Organization et al., 2017) indicates that, the progress made towards SDG #6 maintained existing inequalities, highlighting the need for a broader concept of access to water than the one simply based on the existence of infrastructure. As noted by Aleixo et al. (2019), reducing inequalities from the water and sanitation sector perspective implies not only giving access to infrastructure to marginalized groups, but it requires a multidimensional view to ensure physical and economic accessibility and reliability. Marcal et al. (2024) also show that water insecurity is a multifaceted issue, and that the analysis of inequality in the sector should go beyond access.

We also contribute to discussions on equity which focuses on the fairness of the allocation of water resources. Andres et al. (2021) indicate that, through the use of water tariff design, equity can be promoted among income groups, consumer types, regions, and generations. Furthermore, utility tariffs are commonly considered to be a tool for wealth redistribution in developing countries (Boland and Whittington, 2000). While income taxes should suffice to achieve redistributive goals when governments observe incomes (Atkinson and Stiglitz, 1976), income and wealth are not known for a large share of the population in developing countries where there exist informal labor markets and lack of monitoring systems (Le Blanc, 2008). In this context, the water and sanitation sector may help promote equality.

Moreover, the water economics literature has increasing interest in the relationship between inequalities and water and sanitation, showing that access to improved water services may reduce inequalities associated with water consumption (Aleixo et al., 2019) and result in better living conditions due to time savings and a decrease in water-borne diseases, which may lead to increased work opportunities (Devoto et al., 2012; Koolwal and Van de Walle, 2013; Nauges and Whittington, 2017). Consequently, it may narrow the gap between the poor and the wealthy. However, certain factors, such as the pricing of these services, subsidy targeting errors, and differences in quality and reliability across the population, might actually contribute to fostering inequalities. In spite of the role that expenditures on the water and sanitation sector may have on exacerbating inequalities, just a few studies have focused on inequalities related to tap water expenditures (Sebri, 2015; Martins et al., 2010, 2013; Wietelman et al., 2024) and none of them focused on LAC countries. Moreover, these papers do not incorporate the expenditures on other drinking water sources, such as bottled and truck-delivered water, which can be relevant in contexts with limited access and quality concerns (Zivin et al., 2011) and be more costly than tap water.

1.1 Literature Review

Inequality concerning water and sanitation services is a major problem in developing countries (Deshpande et al., 2020). In this sector, inequality can appear with lower-income households having lower access to clean water, using less water and sometimes paying more relative to higher-income households. The literature has adapted measures of income inequality, such as the Gini index, to measure water-related inequality in developing countries and used the indices to compare inequality levels across different regions within countries. In countries where access to piped water is not universal, there can be large disparities in access to water across households with different levels of income. For instance, Cetrulo et al. (2020) and Malakar et al. (2018) show that in Brazil and India, respectively, lower-income populations have disproportionately lower access to piped water than higher-income populations in most regions of the countries. In these cases, the inequality is measured using a concentration curve showing the cumulative share of the population with water access and the population share ordered by income.

Among households that are connected to the water network, there may also be inequality in water usage. Wang et al. (2012) and Cook et al. (2021) employ a Gini index of water usage to measure this form of inequality in municipalities in South Africa and the Yellow River region in China, respectively. Their analyses underscore that high-income households tend to consume a disproportionately higher volume of water than low-income households in the examined regions. This discrepancy is associated with unstable water supply in drought season and affordability issues. These imbalances can be traced back to the unequal distribution of investments in water infrastructure, favoring wealthier areas. Additionally, the ability of high-income households to choose locations with more reliable services and access to additional resources to cope with unreliable tap water further contributes to the observed disparities.

Besides that, inequality measures can also be used to understand the distributional impact of expenditures on different water sources on the overall inequality. Expenditures on piped water can exacerbate current inequalities as water rates may be regressive by disproportionately burdening lower-income households. In particular, in the absence of adequate subsidy schemes, commonly used fixed fees and increasing block rates may generate higher charges to low-income households, which tend to have a greater number of people in the household and less efficient appliances, resulting in higher water consumption. Sebri (2015) finds that tap water rates are regressive in Tunisía, as the related expenditures are more concentrated than income. Martins et al. (2010) and Martins et al. (2013) show that the income and tap water expenditures are unequally distributed in Portugal using concentration curves and Kakwani Indices. Wietelman et al. (2024) also find that water bills are regressive in California and that drought surcharges do not help in improving progressivity, results that are also discussed using a similar approach with Lorenz curves.

Inequality may also be promoted by water expenses in non-piped water sources. Lack of access to a piped network, problems with water quality, and reliability of the water supply may also affect more low-income households and generate substitution towards other sources of water that tend to be more expensive. For instance, Zivin et al. (2011) shows that in the USA, households increase their consumption of bottled water when there are water quality violations and its costs differ significantly from the water network. However, to our knowledge, no studies have analyzed the contribution of expenditures on different water sources, which may be necessary in the presence of piped water service quality issues in countries, such as those in LAC, to inequality.

Moreover, the LAC region has been historically affected by high inequalities in either consumption or income (Alvaredo and Gasparini, 2015), especially as a middle-income region (Londoño and Székely, 2000). A large body of literature has reported a turning point in total inequality in the early 2000s, resulting in a steady decline (López-Calva et al., 2010) associated with changes in fiscal policy, institutional changes, and trade liberalization, among other factors. However, the economic contraction caused by the COVID-19 pandemic resulted in an increase of around 2% between 2019 and 2020 in inequality as measured by the Gini coefficient. While this is a short-term inequality increase, it can also lead to medium and longer-term increases due to the negative impacts of the pandemic on education in the region (Acevedo et al., 2022). While numerous papers have analyzed inequalities in income (Williamson, 2010; Goñi et al., 2011), education (Torche, 2010), and health (Dávila-Cervantes and Agudelo-Botero, 2019) in the region, studies focusing on inequalities related to access to water and sanitation are scarce.

This paper aims to fill this gap by examining how drinking water expenditures—beyond tap water—affect inequality in LAC countries. This analysis is particularly important given the region's historical and ongoing challenges with inequality in income and access to essential services like water and sanitation.

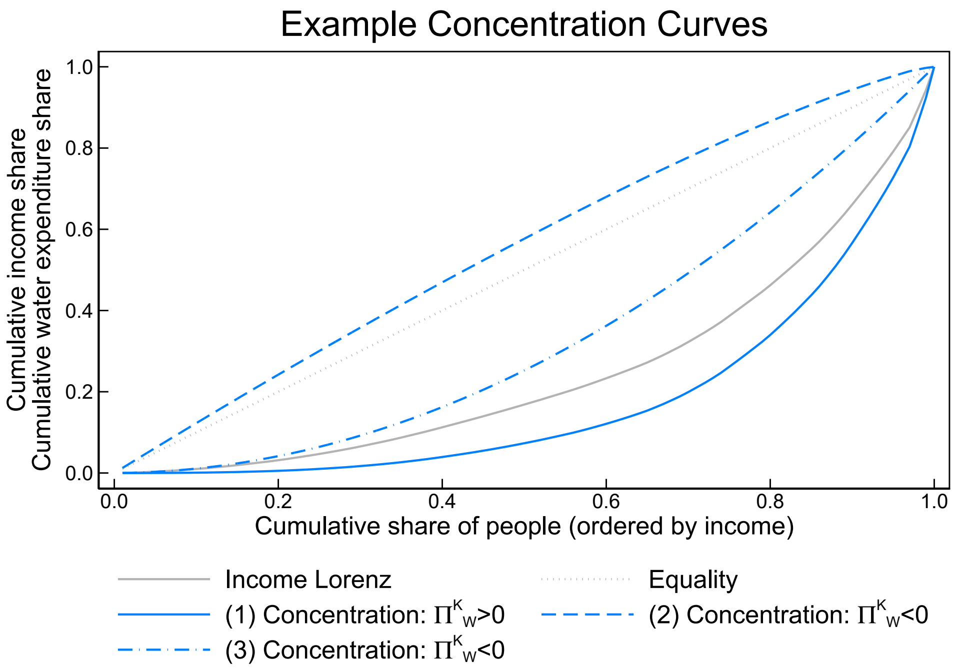
2 Empirical Strategy

In order to assess whether water expenditures are exacerbating inequalities in the region, we use concentration curves, which are graphical representations of the inequality level in the distribution of a specific variable. In particular, it is possible to compare the Lorenz curve, which relates the cumulative proportion of income units ranked in ascending order of income (x-axis) to the cumulative proportion of income perceived (y-axis), and the concentration curve of water expenditures, which represents the cumulative proportion of income units ranked as before (x-axis) to the cumulative proportion of water expenditures (y-axis).

Figure 1 features the Lorenz curve and the concentration curve of water expenditures. When the concentration curve lies completely below (above) the Lorenz curve, water expenditures result in an equalizing (unequalizing) situation. In other words, if the average cost of water is increasing (decreasing) with income everywhere across the distribution, then water expenditures are distributed more unequally (equally) than income, and therefore, the cost of water will be progressive (regressive). Last, the cost of water will be proportional if the concentration curve coincides with the diagonal.

It is also possible to quantify the change in inequality by computing the Kakwani index, defined as the difference between a Concentration index of water expenditures and the Gini index of income, which are based on the concentration and Lorenz curves, respectively. However, as explained by Lustig (2018), the interpretation of the Kakwani index depends on whether the water expenditures generate reranking, i.e., if

Figure 1



Note: Illustrative curves draw with simulated income and water expenditures.

they arbitrarily alter the relative position of households across the income distribution. For instance, there exists reranking if household A was poorer than household B before water expenditures, but B is poorer than A after them. To measure the KaKwani Index and the presence of reranking, we first need to define the three inequality indices needed for the computations: the Concentration index of water expenditures, the Gini index and the Gini index net of water expenditures.

The Concentration index of water expenditures is defined as:

$$C_W^X = \frac{2cov(W, F_X)}{\mu_W} \tag{1}$$

where W is the water expenditures, μ_W is the average value of water expenditures among all households, F_X is the normalized rank of households when they are ranked by their income[1], and $cov(W, F_X)$ is the covariance between water expenditures and the normalized rank of households with respect to their income.

Similarly, the Gini index is computed as:

$$G_X = \frac{2cov(X, F_X)}{\mu_X} \tag{2}$$

[1]To compute the normalized rank we assume that there exist n households ranked by income X from $1/n$ to 1, such that 1 is the rank of the household with the highest income and the one for household j is j/n.

where X represents income, μ_X is the average value of income among all households, F_X is the normalized rank with respect to income, and $cov(X, F_X)$ is the covariance between income and the normalized rank.

We finally have the Gini index net of water expenditures:

$$G_{X-W} = \frac{2cov(X - W, F_{X-W})}{\mu_{X-W}} \tag{3}$$

where $X - W$ represents income net of water expenditures, μ_{X-W} is the average value of income net of water expenditures among all households, F_{X-W} is the normalized rank with respect to income net of water expenditures, and $cov(X - W, F_{X-W})$ is the covariance between income net of water expenditures and its normalized rank. This index measures the distribution of household income after water expenditures.

Having this in mind, the Kakwani index is defined as:

$$\pi_W^K = C_W^X - G_X = \frac{2cov(W, F_X)}{\mu_W} - \frac{2cov(X, F_X)}{\mu_X} \tag{4}$$

In the absence of reranking, the Kakwani index can be directly interpreted as a redistribution measure. The water expenditures are more unequal than the income distribution, if $\pi_W^K < 0$. While they are neutral if $\pi_W^K = 0$ and are equalizing if $\pi_W^K > 0$.

However, when there is reranking the water expenditures could be unequalizing if $\pi_W^K = 0$ and would be equalizing if $\pi_W^K > 0$ and only if:

$$\pi_W^K > \left(\frac{1-g}{g}\right)(G_{X-W} - C_{X-W}^X)$$

where G_{X-W} is the Gini index of income after paying for water, and C_{X-W}^X is the Concentration index of the income after water expenditures with respect to the initial income rank and g is the share of water expenditures with respect to the total income.

To measure the presence of reranking, one can decompose the redistributive effect (RE), i.e., the change in Gini index from the initial income to the Gini index from the income after water expenditures, into vertical equity and reranking:

$$RE = G_X - G_{X-W} = \underbrace{G_X - C_{X-W}^X}_{Vertical\ equity} + \underbrace{C_{X-W}^X - G_{X-W}}_{Reranking} \tag{5}$$

The transition from income pre and post-water expenditures will imply a reduction (expansion) in inequality if the RE takes positive (negative) values. The vertical equity component will take positive (negative) values if the distance between the lower and higher income households narrows (widens), i.e., if higher-income households take a greater (lower) share paying for water. Last, the Reranking component will be equal to zero if the ranking remains unchanged after paying for the water expenses.

3 Data and variables

3.1 LAPOP Survey

We use survey data from the 2021 wave of the AmericasBarometer of the Latin American Opinion Project (LAPOP) from Vanderbilt University. The survey was conducted via phone interviews and is nationally representative of voting-age adults. The samples were built using a multistage probabilistic design and stratified by country regions, municipality size, and urban and rural areas[2].

The survey adopted a "responsive design strategy" where the collected data and para data are continuously monitored during the data collection to address potential biases related to telephone access and response rates (Montalvo et al., 2022). Furthermore, the data is reweighted based on key demographic variables such as sex, age group, and urban/rural geographic location to align with known population proportions, ensuring that weighted measures are representative of the population in each country (Castorena, 2021).

The questionnaire includes questions regarding household characteristics, living situations, utility spending, and public opinion. Based on Section 2, in this paper, the main variables of interest are household income, access to piped water, and expenditures with different water sources.

Our analysis focuses on four countries—Brazil, Colombia, Costa Rica, and Uruguay. Although the LAPOP survey collects data from twenty countries in the Latin American and Caribbean (LAC) region, we have narrowed our sample to enhance the quality of cross-country comparisons. The selection of these countries is based on discussions in Libra (2024), which show that the average access to piped water in these countries, as per LAPOP, corresponds closely with the data from the National Household Surveys for 2021. Differences in how household connections are measured may lead to discrepancies between LAPOP findings and national statistics in other countries.

We chose the LAPOP survey over national household surveys because of its comprehensive coverage of various water sources, including tap water, truck-delivered water, and bottled water. This detailed data allows us to separately analyze access and expenditures for each type of water source, providing insights into the challenges households face and patterns of water inequality. Moreover, LAPOP's standardized data collection methodology across different countries supports robust cross-country comparisons, helping identify regional trends, disparities, and adequate water access and expenditure management practices.

[2]The AmericasBarometer by the LAPOP Lab, www.vanderbilt.edu/lapop

3.2 Household Income

In the survey, household income is reported as a categorical variable. The survey asks what the family income of the households is, including remittances from abroad and the income of all working adults and children. Respondents privately indicate one among five income brackets rather than stating a precise monetary amount to minimize non-response and over and under-reporting (Córdova, 2009).

From the categorical variable, we build a continuous income measure (*income*) following Canavire-Bacarreza et al. (2022), which allows us to compute the inequality indices. Generally, the method consists of using an interval regression model to recover the distribution of incomes within each bracket and use it to impute a continuous measure of income for each observation, as it is further discussed in appendix A.2.

Finally, from the continuous measure of income, we compute the equivalized income to account for differences in household size and composition across countries. We divide the total household income by the square root of the household size, which is a common measure of "equivalent" adults that implies that costs increase with size at a diminishing rate.

3.3 Water Expenditures

Survey respondents also report monthly expenditures incurred by households in three different water sources: tap water, bottled water and water purchased from trucks and vendors. As seen in Martinez-Espiñeira and Urdiales (2024), these three types of water expenditures are not mutually exclusive, as a household can use a type of water source as primary and complement it as needed with other sources. Having this in mind, we define two water expenditure measures. The first variable, *Exp tap water* is defined as the household monthly expenditure on tap water. The second measure, *Exp total water*, is computed as the sum of expenditure on tap and bottle water, and water truck delivering service. Water expenditure is also equivalized to take household size into account, following the same procedure as for income.

Furthermore, all monetary variables are translated into Purchasing Power Parities (PPP) and expressed in US dollars (USD) to control for differences in price levels and to equivalize the purchasing power of currencies when we compare these variables across the LAC countries.

3.4 Other variables

While the abovementioned variables represent the main information used to construct the different Gini and Concentration indices, we also use information on water access and main drinking water source for descriptive purposes. In particular, we construct the dummy variable *Tap access* that takes value 1 if household i reports expenditure on tap water, 0 otherwise. In order to control for those households who may have access to tap water but do not pay for it in cases there is a basic amount of water subsidized, this variable also takes value 1 if a household reports tap water expenditures equal to 0, but indicates that the primary source of water for either drinking or other purposes is tap. Moreover, we construct three dummy varibles *Tap drinking Bottled drinking*, and *Other drinking* that take value 1 if household *i* indicates that their primary source of drinking water is tap, bottled or other source,[3] respectively, and 0 otherwise.

Table 1 shows descriptive statistics aggregated for the four countries and the variables used in the analysis. There exists a wide level of heterogeneity for all the variables considered, which will be disentangled in the next section.

Table 1: Descriptive statistics for Brazil, Colombia, Costa Rica and Uruguay

	mean	sd	min	max	count
Income (USD PPP)	1,391.38	1,296.40	172.52	7,246.77	5,318
Exp tap water (USD PPP)	63.53	510.85	0.00	25,403.87	4,745
Exp total water (USD PPP)	92.14	676.82	0.00	27,520.86	3,132
Tap access (share)	0.90	0.30	0.00	1.00	5,527
Tap drinking (share)	0.71	0.45	0.00	1.00	5,465
Bottled drinking (share)	0.18	0.38	0.00	1.00	5,465

4 Results

4.1 Exploratory analysis

In this section, we delve into a graphical comparison of access to tap water across the analyzed countries, shedding light on variations in water sources and expenditures.

We begin our analysis by graphically comparing the levels of access to tap water across the countries considered in the analysis. Figure 2 shows that access to tap water is relatively high across the four countries considered, with Brazil having the lowest access to tap water rate. However, there are wide differences in the main water source used for drinking. While Uruguay has the highest access to tap water, it is also the one with the lowest proportion of households reporting using this water source for drinking purposes. Consequently, almost 40% of the households indicate they rely on bottled water for drinking. On the contrary, Costa Rica and Colombia report shares of *Tap drinking* close to those of *Tap access*.

Table 2 compares the rate of access to tap water with the share of expenditures on tap and bottled water over the total. In line with the discussion above, Uruguay has the highest share of expenditures on bottled water over the total despite having the highest level of access. Surprisingly, the portion of total water expenditures devoted to bottled water is relatively high in Costa Rica.

[3]The possible answers to the question related to main drinking water source are provided in Appendix A.1.

Figure 2: Access to piped Water/ Sources of Drinking Water

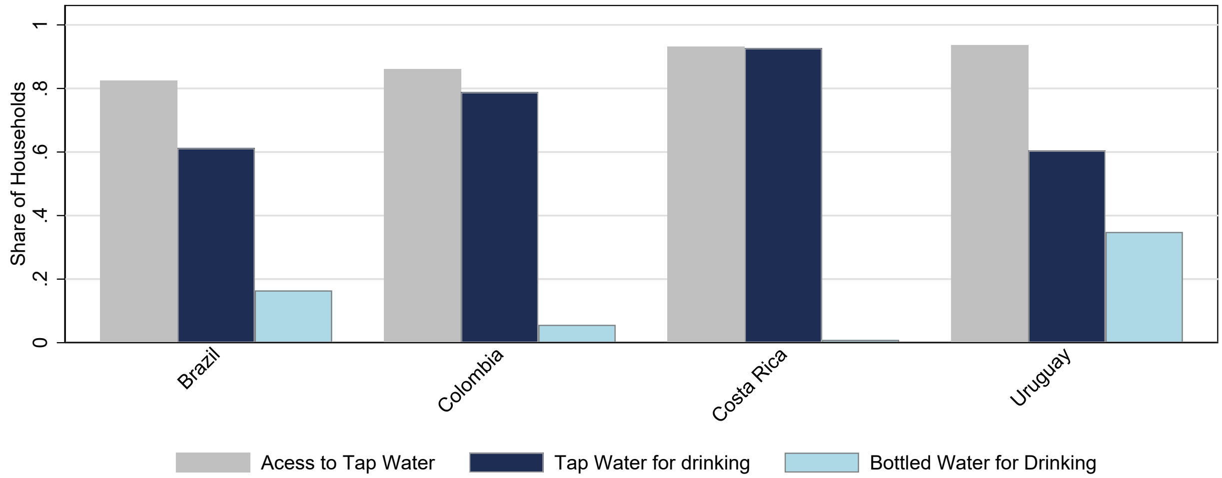


Table 2: Mean share Access to tap water, tap and bottled water expenditures over the total

Country	*Tap access*	$\frac{Exp\ tap\ water}{Exp\ total\ water}$	$\frac{Exp\ bottled\ water}{Exp\ total\ water}$
Brazil	0.82	0.63	0.38
Colombia	0.86	0.84	0.19
Costa Rica	0.93	0.67	0.35
Uruguay	0.94	0.59	0.44

Part of these differences in water access may be related to differences in income distribution across these countries. As depicted in Figure 3, Uruguay has the highest average income, followed by Costa Rica, Brazil, and Colombia. However, Costa Rica and Uruguay exhibit higher variations in reported household income than Brazil and Colombia.

Despite the differences in income, in all countries, households spend around 5% or less of their income on water expenditures, as shown in Figure 4. Although Colombia has lower income, households spend on average a slightly higher share of their income on water expenses and there is higher variation on this share compared to the other countries. Consistent with Figure 2, most households in Costa Rica use tap water for drinking so the total share of water expenses and the share spent on tap water are very similar. While for Uruguay, as more people use bottled water for drinking the total share of expenses with water is higher than those with tap water.

Looking at the share of income devoted to water expenditures by income quintile within each country, we find that low-income households allocate a higher proportion of their income to water expenditures than high-income households. This regressive pattern appears in all countries in our sample. However, the extent of this regressive pattern varies across countries. For instance, in Colombia (Figure 5b), where significant subsidies for tap water expenditures are available, the disparity in the share of income spent

Figure 3: Income Distribution

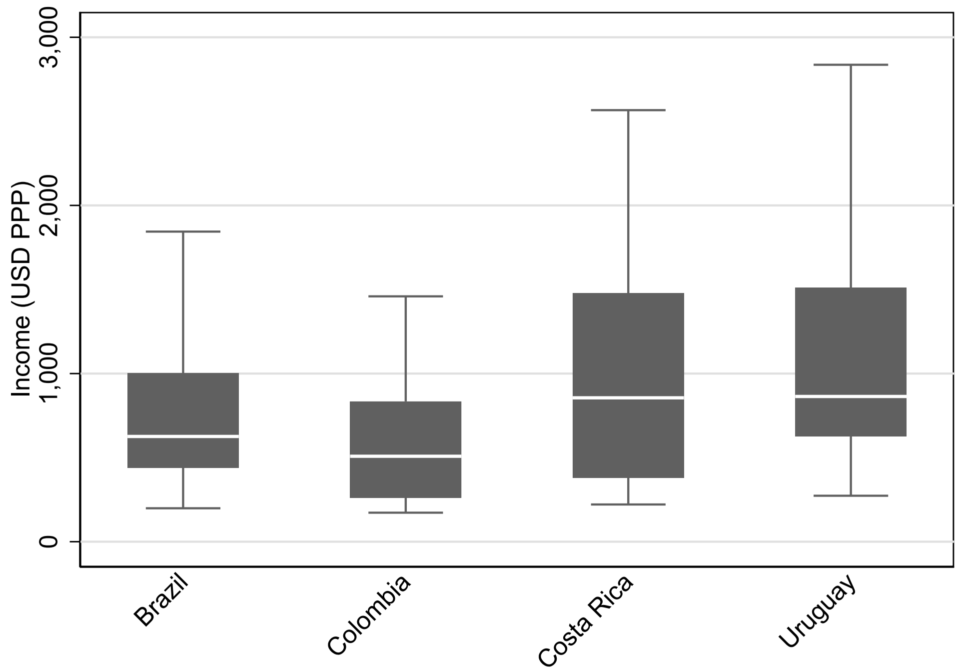
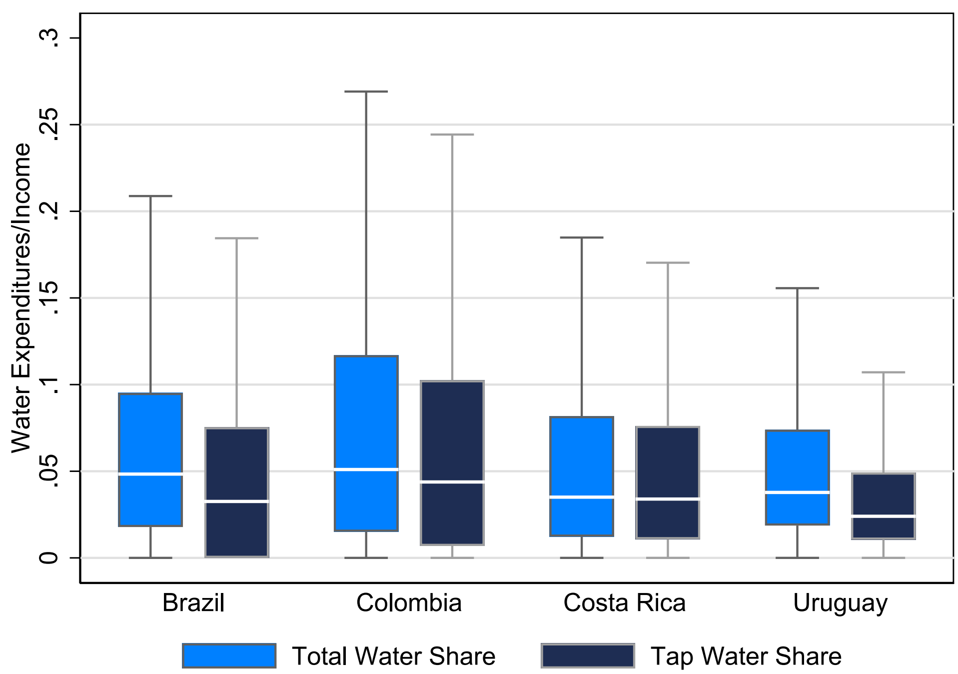


Figure 4: Share Water Expenditures over Income



on tap water between income groups is smaller than that found in Brazil (Figure 5a). In Costa Rica, the proportion of income used to pay for water increases substantially when considering other sources of water such as bottled water for households in the first quintile, whereas the increase is relatively small for that quintile in Colombia.

Figure 5: Water Expenses by Income

(a) (b)

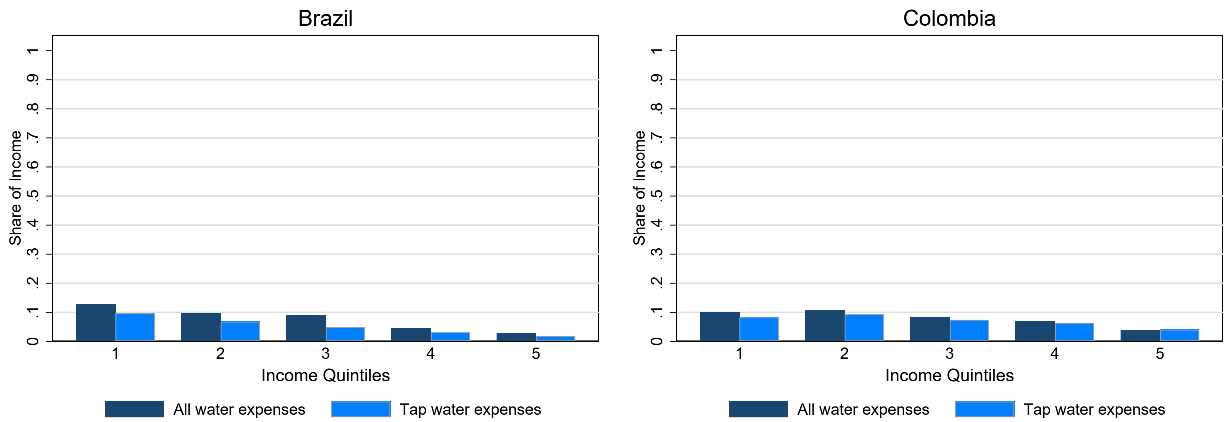
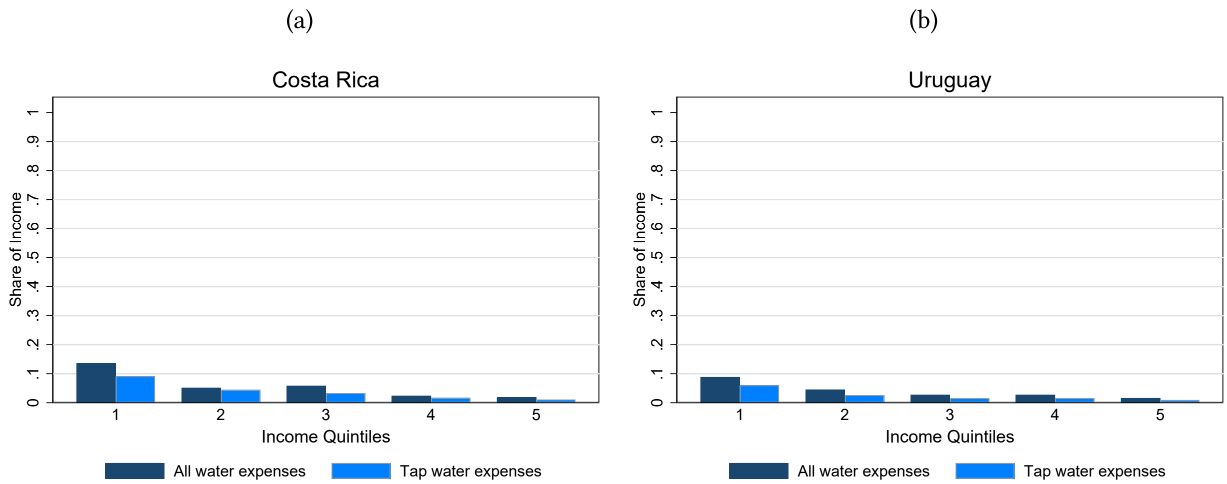


Figure 6: Water Expenses by Income



Although water expenditures constitute a relatively small portion of overall income, the fact that lower-income households bear a disproportionately higher burden of water expenditures may contribute to the exacerbation of income inequality in the region. In the following section, we will present measures of water expenditure inequality and conduct a comparative analysis across countries.

4.2 Concentration and Lorenz curves

Next, we plot the Lorenz and concentration curves for tap and total water expenditures by country (Figure 7). We observe that the concentration curves for tap and total water expenditures lie above the Lorenz curve for all the countries considered, but there are substantial differences across them.

The smallest distance between the curves is observed for Colombia. Specifically, our analysis reveals that the first income quintile holds 5% of the aggregate income but accounts for 8% of the cumulative tap water expenditures. This indicates that while poorer households still pay a higher proportion of their income for water—demonstrating the regressive nature of water expenditures—the existing subsidy schemes help achieve a distribution of tap water expenditures that is relatively close to the distribution of income. Notably, there is a significant increase in the distance between the curves around the median household income, gradually decreasing as income rises, indicating that water expenditures are more regressive for those around that income level.

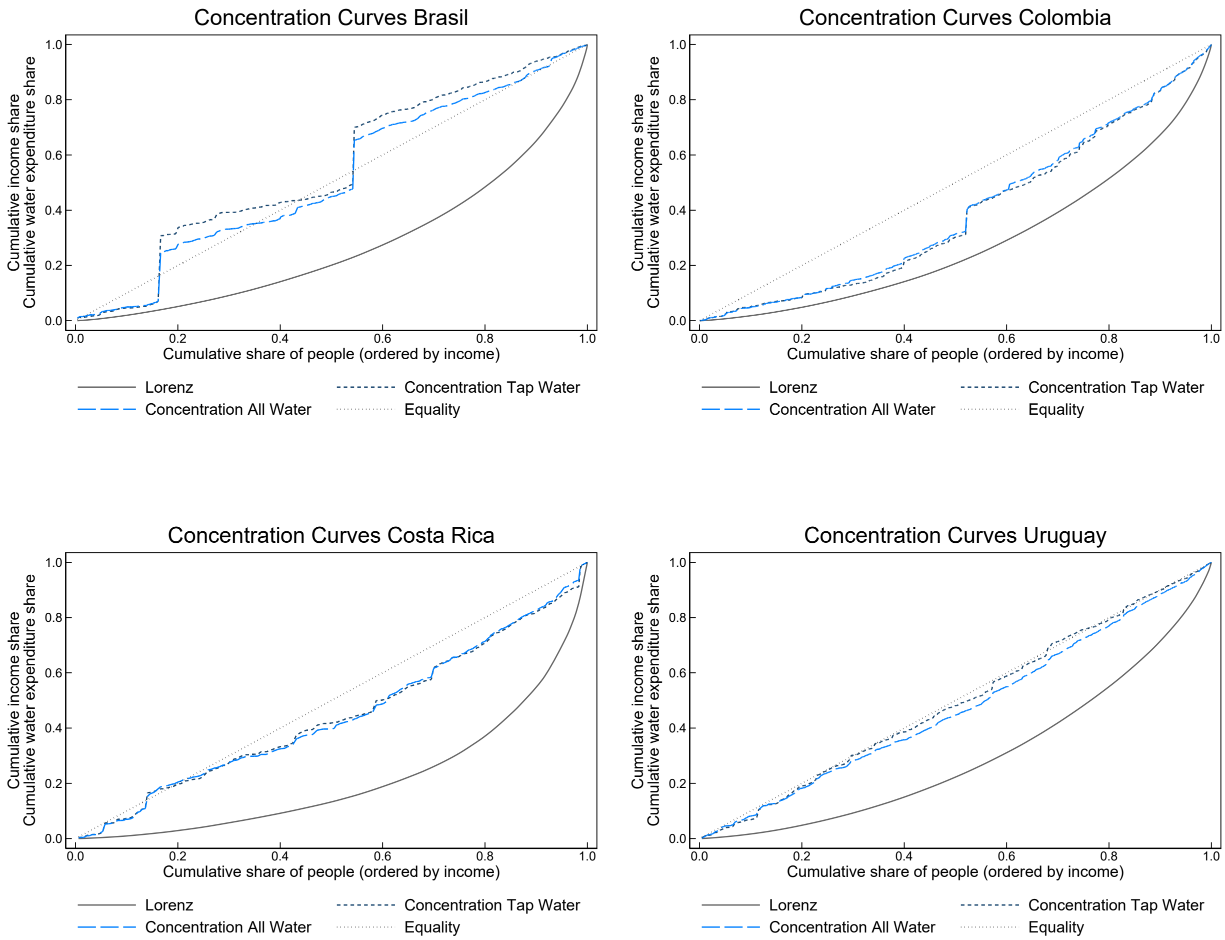
The concentration curves for Uruguay predominantly align with the 45-degree line, with occasional sections slightly above it, indicating that households across different income levels spend similar amounts on water expenditures. This pattern is particularly evident in the first income quintile, which accounts for 20% and 19% of the cumulative tap water expenditures while holding only 3% and 5% of the income in Costa Rica and Uruguay, respectively.

Lastly, Brazil shows the largest differences between the curves, with the concentration curves for tap and total water expenditures mostly lying above the 45-degree line. This regressive situation is evident in the first income quintile, which holds around 5% of aggregate income but bears about 34% of the cumulative tap water costs.

As noted in Section 2, these results imply that water expenditures are generally distributed more equally than income, resulting in an unequalizing situation. That is, water expenditures tend to exhibit a high degree of homogeneity across households, resulting in a regressive cost of water. Water expenditures depend both on water consumption and the cost of water. The latter encompasses not only the rate for tap water but also the prices of bottled water and water truck delivery services when considering total water consumption that includes averting behaviors.

While the correlation between water consumption and income is usually positive but small (Russell and Fielding, 2010; Makki et al., 2015; Whittington et al., 2015; Nauges and Whittington, 2017), the prevalence of subsidy schemes in the water and sanitation sector in Latin America could result in tap water expenditures distributed more similarly to income if subsidies were adequately targeted. However, as shown by Gómez-Lobo and Contreras (2003) and Cunial and Pérez-Urdiales (n.d.) for the case of Colombia, targeting errors are quite large. Moreover, when we consider other expenditures such as those in bottled water and water truck service delivery that are not subsidized, these may represent a substantial effort for lower-income households if they need to substitute for tap water.

Figure 7: Concentration curves by country



4.3 Gini, concentration and Kakwani indices

Following Section 2, to further quantify the relationship between the income and water expenditure distributions, we first compute the Gini index, the Gini index net of tap water expenditures (Table 3) and the decomposition of the redistributive effect into the vertical equity component and the reranking component. Then, we repeat these computations considering total water expenditures (Table 4).

The Gini index shows substantial income inequality across the countries considered in the analysis, being Costa Rica the one with the highest value. It should be noted that the Gini indexes calculated in this paper may differ from those computed by the World Bank[4], as they utilize income data from national household surveys (World Bank, 2024), whereas our analysis is based on LAPOP data. Comparing Gini indexes computed from national surveys across countries can be challenging due to several factors. Differences in data collection methods, timing, definitions of income, variations in household structures, and

[4]World Bank Gini Index data available at https://data.worldbank.org/indicator/SI.POV.GINI

the exclusion of non-monetary income can significantly affect the calculations. With LAPOP we can guarantee that the same methods and definitions were used in all surveyed countries. Moreover, calculating the Gini Index using equivalized income is another factor contributing to potential differences from the statistics reported in other studies, which may only consider raw household income measures without adjusting for household size.

On Table 3, the Gini index net of water expenditures is higher for all the countries considered. Brazil is the country showing the largest change from the Gini index to the Gini index net of both tap water and total water expenditures. It also exhibits the largest negative vertical equity component, which implies that water expenditures widen the distance between higher and lower-income households. Moreover, the reranking component differs from zero and is particularly large when considering total water expenditures. This result indicates that the rank across the income distribution changes due to the proportion of income devoted to paying for water. Costa Rica and Uruguay, the countries with the highest tap access rate, show the smallest change from the Gini index to the Gini index net of water expenditures. Moreover, this change is approximately fully due to changes in vertical equity.

Table 3: Redistributive effect decomposition considering Tap Water expenditures

Country	Gini	Gini Post Tap Water	Redistribution Effect Tap Water	Vertical Effect Tap Water	Reranking Effect Tap Water
Brazil	0.447	0.496	-0.048	-0.040	-0.009
Colombia	0.438	0.469	-0.031	-0.024	-0.007
Costa Rica	0.543	0.556	-0.014	-0.013	-0.000
Uruguay	0.401	0.412	-0.012	-0.011	-0.000

Table 4: Redistributive effect decomposition considering Total Water expenditures

Country	Gini	Gini Post All Water	Redistribution Effect All Water	Vertical Effect All Water	Reranking Effect All Water
Brazil	0.447	0.509	-0.062	-0.040	-0.022
Colombia	0.438	0.475	-0.037	-0.022	-0.015
Costa Rica	0.543	0.562	-0.019	-0.018	-0.001
Uruguay	0.401	0.418	-0.017	-0.017	-0.001

Next, Table 5 presents the Gini index, and the concentration and Kakwani indices for tap and total water expenditures by country. The concentration index for tap water expenditures shows values much closer to 0 than the Gini index for most countries. As previously discussed, tap water expenditures are more equally distributed than income, as these expenditures seem similar across households regardless of their income.

The concentration index for tap water expenditures takes negative values for Brazil and Uruguay, which implies that tap water expenditures are higher among poorer households in these countries. This result aligns with Figure 7, where this pattern can be seen through the concentration curves with sections above the equality line.

The negative Kakwani indices, computed as the difference between the Concentration index of water expenditures and the Gini index, show that both tap water and total water expenditures are unequalizing. Following Section 2, given that the Kakwani indices take negative values, the rerank effect generated by water expenditures does not affect the interpretation. The unequalizing result is consistent with the regressive pattern shown in the descriptive evidence where lower-income households spend a higher share of their income on water expenditures than higher-income households.

Table 5: Gini index, Concentration index of tap and total water expenditures and Kakwani Index by country

Country	Gini	Concentration Tap water	Kakwani Tap water	Concentration All water	Kakwani All Water
Brazil	0.447	-0.090	-0.537	-0.023	-0.470
Colombia	0.438	0.239	-0.200	0.225	-0.214
Costa Rica	0.543	0.108	-0.435	0.113	-0.429
Uruguay	0.401	-0.001	-0.401	0.051	-0.349

However, the relationship between water expenditures beyond tap water and inequality is not straightforward. The pattern varies across different countries. In Brazil, Costa Rica, and Uruguay, the concentration index of total water expenditures is higher than that of only tap water expenditures. This suggests that total water expenditures are distributed more similarly to income than tap water alone. Nevertheless, the Kakwani indices for tap and total water expenditures are both negative for these three countries, implying that water expenditures are generally regressive.

In Colombia, the concentration index of tap water expenditure is slightly higher than that of total water expenditures, but still lower that the Gini index. Consequently, the Kakwani indices for this country take negative values, although these are the smallest ones, in absolute terms, across countries. As seen in Table 2, Colombia is the country with the highest proportion of total water expenditures devoted to tap water (84%).

In the next section, we further discuss our results, suggest some potential factors contributing to them and derive policy implications.

4.4 Discussion

As seen above, while water expenditures are generally unequalizing in the countries considered in the analysis, substantial differences exist across countries.

Tap water represents the highest share of expenditures over the total, with tap water expenditures mostly defined by water tariffs and consumption, which has a positive but weak relationship with income. Consequently, the Concentration index of tap water expenditures may be mainly driven by the water tariff systems implemented in each country.

The most common tariff structure in the countries considered in the analysis when consumption is measured is a two-part tariff, which includes a fixed fee and a volumetric component usually defined as Increasing Block Rates (IBR) or uniform rates. IBR are progressive in consumption, as the per unit price of water increases when consumption reaches certain thresholds. This structure can be detrimental for larger households, which tend to be lower-income households, as IBRs lead to higher per capita payments (Pérez-Urdiales and Baerenklau, 2019; Arbués and García-Valiñas, 2020). Considering that, and as seen in López-Ruiz et al. (2024), Brazil and Uruguay are the countries where we observe the highest average increase in water bills as the number of people living in the house grows.

It is also important to consider that the water and sanitation sector in LAC is heavily subsidized, but significant differences exist in the subsidy systems across countries. The variation in the groups of consumers targeted by these subsidies in each country could account for some of the differences in inequality concerning tap water expenditures.

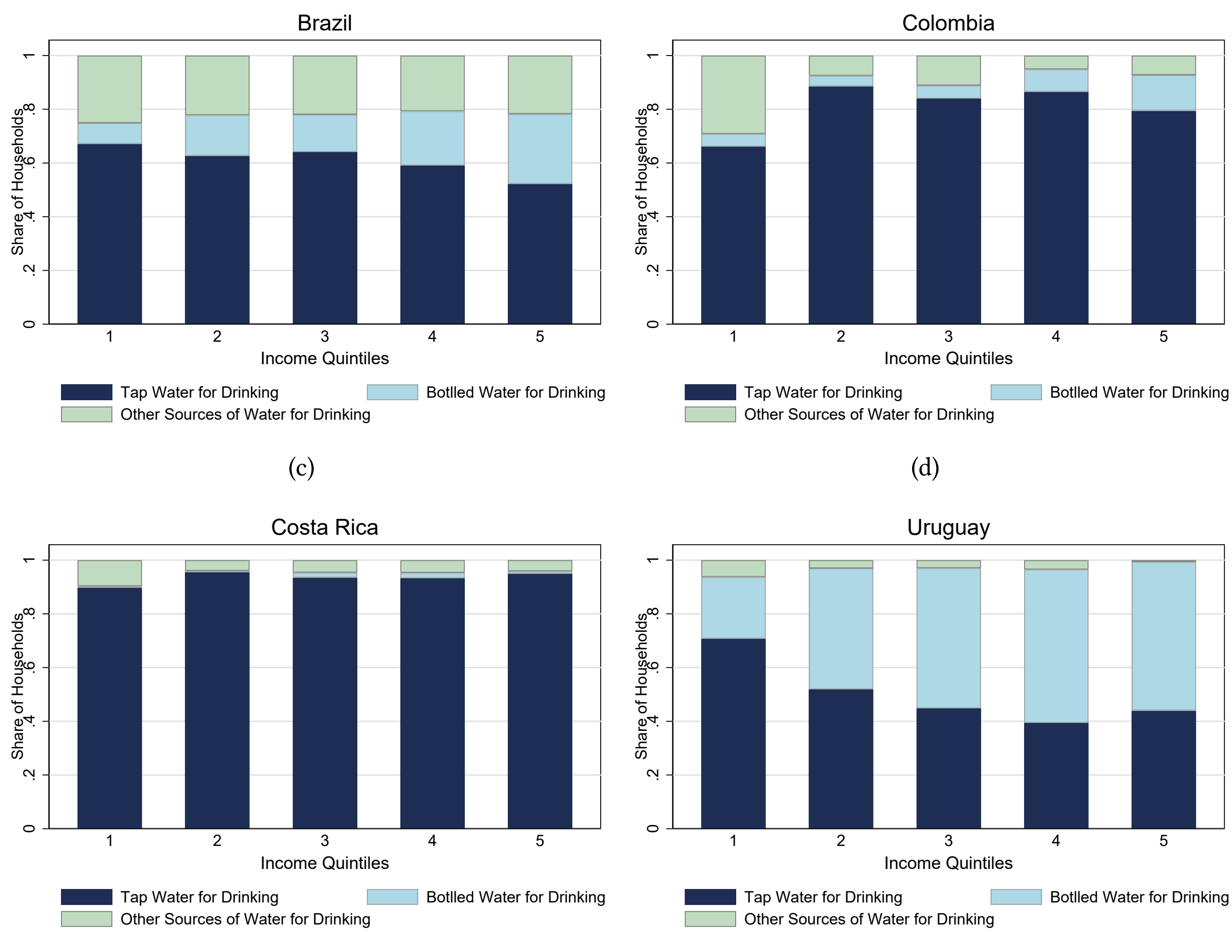
In Brazil, demand subsidies are widely implemented. López-Ruiz et al. (2024) find that 80% of the country's municipalities use them. In particular, households are classified into two main categories: regular and social consumers. However, there is no consensus on the economic criterion used to define the social category. While in some cases, social consumers are those whose household income is less than three times the minimum wage in many municipalities, this criterion is much stricter in other municipalities, being the threshold 2, 1 or even 0.5 times the minimum wage. As a result, subsidies may only cover extremely poor households in some municipalities. Cadastro Único, Brazil's low-income households registry database, is used in some other municipalities, which may also result in difficulties reaching the poor who are not registered (De la Brière and Lindert, 2005).

In Colombia, consumers are classified into different strata based on Law 142 of 1994, "Ley de Servicios Pblicos". The strata system identifies households' payment abilities based on houses' exterior characteristics and those of their neighborhood (Medina et al., 2007). Municipalities set the boundaries that divide the different socioeconomic strata and use this classification to implement a cross-subsidy system that charges subsidized water and sanitation tariffs to households located in lower strata and surcharge tariffs to those in higher strata. Costa Rica set a national cross-subsidy system for the water and sanitation sector covering households in poverty and extreme poverty (Executive decrees N.39757 MINAE of 2016 and N.40711 MINAE of 2017). However, López-Ruiz et al. (2024) could only identify the presence of subsidies in about 8% of the municipalities. Last, Uruguay implements subsidized water and sanitation tariffs using age, economic characteristics and rural location as elegibility criteria, resulting in different benefit levels depending on the criterion used.

While expenditures on other sources, mainly bottled water, do not account for most of the total water expenditures, they could play a relevant role in the redistributive impact of water expenditures on overall inequality. As discussed above, the distribution of total water expenditures is more similar to income. One potential explanation for this result arises from Figure 9, where we observe that the share of households reporting bottled water as the primary drinking source generally increases with income. This situation is more apparent in the cases of Brazil and Uruguay, which are also the countries with the largest differences between the concentration index for tap water expenditures and that of total water expenditures.

Figure 9: Drinking Sources by Income

(a) (b)



Despite the proportion of water devoted to drinking purposes not being large, the substantially higher price of bottled water, compared to the low per unit cost of tap water (Walter et al., 2017), strongly affects the total water expenditures. As a result, total water expenditures are not as homogeneous across households as tap water expenditures, with high-income households devoting a greater portion of their income to paying for bottled water. While total water expenditures seem less unequalizing than tap water expenditures alone, this result may not be desirable. Martinez-Espiñeira and Urdiales (2024) compute bottled water expenditures adjusted by normative reasons, i.e., that would exclude expenses due to habits or consumers' perceptions and taste. This correction resulted in a relatively small downward shift in bottled water expenditures, which partly indicated that, in this particular study, the main reasons to consume bottled water may be deemed legitimate from a normative perspective.

Similarly, Table 6 shows that the main reasons given by the respondents in Brazil and Uruguay, where we observe the greatest change from tap water expenditures to total water expenditures, to drink bottled water is the fear of contamination in the tap water or better quality. Nevertheless, other reasons seem to play an important role in the case of Brazil too. Avoiding contamination is also the main reason in Costa Rica, whereas other reasons are the main driver in Colombia, followed by avoiding contamination. In this context, if tap water is indeed contaminated, it is also a problem that disproportionately affects low-income households with less resources to substitute away from the contaminated source. Therefore, despite total water expenditures leading to a less unequalizing situation than that of tap water expenditures alone, this result may mask inequalities in access to water quality coping strategies, which require further research.

Table 6: Reasons Bottled water

Country	Better Taste	Better Color	Better Quality	Avoid Contamination	Better Availability	Custom	Other Reasons
Brazil	0.13	0.03	0.36	0.15	0.00	0.01	0.31
Colombia	0.00	0.00	0.11	0.34	0.03	0.04	0.48
Costa Rica	0.13	0.00	0.19	0.38	0.06	0.10	0.15
Uruguay	0.16	0.00	0.25	0.27	0.00	0.09	0.23

5 Conclusions and policy recommendations

Over the past decades, Latin American countries have grappled with the persistent issue of inequality. In response, they have implemented various traditional strategies, including cash assistance programs for low-income households, educational quality enhancements, and subsidized public services. Within this context, the water and sanitation sector stands out as heavily subsidized, with subsidies accounting for approximately 1.96-2.4% of the regional GDP (Andres et al., 2021).

Water tariffs, typically designed to achieve objectives such as efficiency, cost recovery, and environmental conservation, are also commonly used to redistribute income among consumer groups in developing countries where informal labor markets and a lack of monitoring systems make achieving redistributive goals through income taxes difficult. However, it is essential to recognize that using water tariffs for redistributive purposes inadvertently excludes households without access to water services, potentially leaving those in greater need behind.

This study is the first to analyze the role played by total water expenditures, encompassing not only tap water expenditures but also those in bottled water and water delivered by trucks, in exacerbating inequalities in the Latin America and Caribbean (LAC) region. Drawing on data from four countries, we uncover a noteworthy pattern: water expenditures are more equally distributed than income, leading to an unequalizing outcome. Specifically, households consistently allocate similar payment amounts for water, irrespective of their income levels, resulting in a regressive trend. This phenomenon holds true for both total water expenditures across the four countries and, notably, for tap water expenses.

Anticipating the behavior of tap water expenditures, one might assume less regressive patterns. After all, the heavy sector subsidies and comprehensive policies to ensure water tariff affordability (Andres et al., 2021) should mitigate disparities. However, a closer examination reveals that water expenditures impose a higher financial burden on low-income households, particularly in Brazil and Uruguay, where economically disadvantaged households actually pay more for their water than their high-income counterparts. As explained in the discussion section, this result may be due to the type of tariff structure prevalent in the region, coupled with varying subsidy eligibility criteria, which may lead to targeting issues.

While total water expenditures remain unequalizing, they exhibit a distribution more akin to income levels than tap water expenditures. However, this seemingly equitable outcome may mask inequalities in access to water quality coping strategies. Notably, higher bottled water consumption among wealthier households, driven by water quality concerns, could distort the overall picture.

The challenge of addressing inequalities in Latin America extends far beyond the water and sanitation sector. However, this paper sheds light on the role of water expenditures in exacerbating these disparities. While further research is warranted, our descriptive analysis in the discussion section underscores the urgent need to refine water tariff structures and subsidy targeting. Simultaneously, improving water quality is an essential step toward reducing inequalities within this critical sector.

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A Appendix

A.1 Main drinking water sources

The 2021 wave of the AmericasBarometer asked survey respondents about their primary source of drinking water. Only one source, the most used, had to be chosen by the respondent in the following list:

(01) Piped/tap water or public water/ from the network/tap/sink inside of the house

(02) Piped/tap water or public water into the yard/plot outside of the house

(04) Community tank/tap for public use

(05) Tubed well/borehole (with pump)

(06) Covered dug well (without pump)

(07) Uncovered dug well (without pump)

(08) Covered spring

(10) Rainwater collection

(11) Bottled water (water bottle/ bagged water)

(13) Truck/water pipe/water tank/water carrier

(14) River, stream, canals, irrigation channels

(77) Other

A.2 Income Imputation

In order to use the information on income in our data to measure inequalities, we follow an imputation approach that simulates the distribution of the data reported in brackets. Specifically, we adopt a multiple imputation approach that accounts for the censored nature of the dependent variable Royston (2007); Rios-Avila et al. (2024) 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[5] reported, the probability that a household's income falls

[5]Note that, in order 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.

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:

$$Income_i^* = x_i'\beta + u_i^* \tag{6}$$

, 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 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:

$$Income_i^*|x_i \sim N(\mu(x), \sigma(x)) \tag{7}$$

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,

$$Pr[a_k < Income_i^* \leq a_{k+1}] = Pr[Income_i^* \leq a_{k+1}] - Pr[Income_i^* \leq a_k] = \Phi^*(a_{k+1}) - \Phi^*(a_k) \tag{8}$$

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

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

$$logL = \sum_{i=1}^{N}\sum_{k=1}^{K} d_{ik} ln[\Phi^*(a_{k+1}/x_i) - \Phi^*(a_k/x_i)] \tag{9}$$

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 Rios-Avila et al. (2024), 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:

$$u_i^* \ \epsilon \ \left[\frac{a_k - \mu(x)}{\sigma(x)}, \frac{a_{k+1} - \mu(x)}{\sigma(x)}\right] \tag{10}$$

Then, following Rios-Avila et al. (2024), we can impute values for $Income_i^*$ by getting random draws for u_i^* as follows:

$$\tilde{u_i} = \Phi^{-1}(r_i) \tag{11}$$

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

$$r_i \sim \ uniform \ [\Phi(\frac{a_k - \mu(x)}{\sigma(x)}), \Phi(\frac{a_{k+1} - \mu(x)}{\sigma(x)})]. \tag{12}$$

Therefore, we can construct:

$$\widetilde{Income}_i = x_i'\hat{\beta} + \tilde{u}_i \tag{13}$$

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:

$$\begin{bmatrix} \tilde{\mu}(x) \\ \tilde{\sigma}(x) \end{bmatrix} \sim \begin{pmatrix} \hat{\mu}(x) & , \tilde{\Omega} \\ \tilde{\sigma}(x) & \end{pmatrix} \tag{14}$$

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:

$$\tilde{\tilde{u}}_i = \Phi^{-1}(\tilde{r}_i) \tag{15}$$

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

$$\Phi^{-1}(\tilde{r}_i) \sim \; uniform \; [\Phi(\frac{a_k - \tilde{\mu}(x)}{\tilde{\sigma}(x)}), \Phi(\frac{a_{k+1} - \tilde{\mu}(x)}{\tilde{\sigma}(x)})] \tag{16}$$

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

$$\widetilde{\widetilde{Income}}_i = x_i\tilde{\beta} + \tilde{\tilde{u}}_i \tag{17}$$

Once the imputed income is obtained, standard aggregation methods such as Rubin (1988) are used to analyze inequalities as if the income variable were fully observed.