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Abstract

An issue that affects the effectiveness of water pricing policies is consumers' misperception, which implies that households decide their water consumption based on poor/inaccurate information about the marginal price. We use household survey data on bill and quality perception in Brazil to analyze this problem and its drivers. Once we control for the selection bias caused by survey respondents voluntarily providing their bill, we find evidence of bill misperception. Apart from the informational and socioeconomic drivers usually considered in the literature, perceived water quality seems to be a relevant factor of the degree of misperception.

1. Introduction

Pricing policies in the water sector are important demand-side strategies commonly implemented to manage water resources. Water tariff design involves a complex dilemma to balance conflicting objectives such as efficiency, equity, cost-recovery, affordability and environmental sustainability (Grafton et al., 2020). However, achieving these objectives may be hindered if price information is not clear and conveniently available to consumers. If there exists misperception of the bill that consumer pay for the service they receive, pricing policies may not be effective, which is particularly worrisome in the case of urban areas in developing countries such as those in Latin America and the Caribbean (LAC), where there is increasing water stress partly due to the mismatch between the distribution of water resources and the growing populations (Libra et al., 2022). Moreover, price misperception may lead to suboptimal choices, which can cause losses in social welfare. For instance, Ito (2014) finds that consumers response to average price rather than marginal may result in a slight increase in aggregate consumption in the case of nonlinear tariffs. Moreover, the author shows that a suboptimal choice may change the efficiency cost of nonlinear pricing depending on the social marginal cost of water consumption. In particular, the efficiency cost increases if the social marginal cost is high due to negative externalities. Last, numerous studies guiding water policy rely on household survey data with self-reported information on prices and water bills (Karuaihe, Wandschneider and Yoder, 2012). In this case, price and bill misperception may invalidate their results, and therefore, lead to inadequate policy recommendations.

A growing literature analyzes the drivers of price misperception in the residential water sector, focusing on European countries and the United States. However, as far as we are aware, there are no previous studies focusing on developing countries, where the level of information may be lower, given that individual metering is not as extended as in developed economies, and there are frequent water quality issues that may influence consumers perception of the service.

In this paper, we use data obtained from a survey on bill and quality perception in Brazilian households in 2019, as well as on socioeconomic characteristics, information factors and actual water bills. This dataset is of particular interest for two main reasons. First, while Brazil has historically been a water-rich country, more than half of the country's population lives in areas with medium-high to extremely high-water risk when considering quality-based physical water risk, quantity-based physical water and regulatory and reputational risk (Libra et al., 2022). In this context, effective water pricing policies can provide incentives to achieve efficient allocation of water resources if consumers have accurate price information to adjust their behavior accordingly. Second, while there exist national water quality standards, contaminants in tap water tend to exceed the limits established in Brazilian regulations, especially in areas such as urban slums. In the absence of adequate price information, price perception may be influenced by the water quality, which is observed easier by the consumer through sensorial factors such as clarity and taste. However, it is important to note that the database does not provide information on price perception. Instead, consumers were asked about how much they believe they paid for their water bill in the last billing period. As noted by Brent and Ward (2019) and Pérez-Urdiales and Baerenklau (2019a), consumers are more likely to have a better understanding of their bill rather than precise knowledge of their marginal price, especially when they face complex water tariffs such as Increasing Block Rates. Having that in mind, we analyze bill misperception, i.e., the degree of inaccuracy between how much consumers believe they pay and how much they actually pay, as a proxy indicator of price misperception.

Our results show that, while households who report their water bill are generally well-informed, bill misperception is higher when controlling for sample selection bias due to households voluntarily reporting their bill. Moreover, those who perceive water quality as bad or very bad also tend to show higher bill misperceptions. This is a relevant finding for policymakers because if poorer households report lower levels of (perceived) water quality, welfare losses will be higher for this segment of the population.

The paper has the following structure. In Section 2, we briefly discuss the different factors influencing the level of price and bill misperception included by the previous literature and the contribution of this study in the context of a developing country. Section 3 describes the Brazilian pricing and water quality framework. In Section 4 and 5 we present the empirical strategy and data, respectively. The estimation results are presented and discussed in Section 6. The paper concludes with a summary of the main results and policy implications.

2. Hypotheses

Water pricing is a crucial policy decision that influences the revenues of water utilities, operating and investment decisions, and future supply levels (Grafton et al., 2014). However, this decision may have undesirable effects if consumers' perceptions are not accurate as they influence their responsiveness to price, and eventually consumption.

While pricing policies are usually based on the assumption of perfect rationality (García-Valiñas et al., 2021), empirical evidence points towards the assumption of bounded rationality, i.e., consumers decisions are impacted by cognitive costs and imperfect information, among other factors. Given the complexity of the prevalent nonlinear water tariffs such as Increasing Block Rates (IBR), previous studies have shown cognitive difficulties in understanding nonlinear prices (De Bartolome, 1995; Ito, 2014). Imperfect information is also commonly found in the residential water literature, with consumers indicating not being well informed about the pricing scheme (Pérez-Urdiales et al., 2016), or being exposed to very heterogeneous levels of price information via their water bills (Gaudin, 2006).

There is an increasing number of studies analyzing price misperception among residential water consumers. Using survey data from Réunion (France), Binet et al. (2014) find that residential consumers tend to underestimate the price of water, resulting in an overconsumption of water. Brent and Ward (2019) conduct a randomized field experiment in Melbourne (Australia) and show that, while consumers overestimate the price of water, they seem to be better informed about their water consumption and bill. García-Valiñas et al. (2021) analyze the factors influencing the degree of misperception of water consumption and bill for a sample of households in Granada (Spain), including socioeconomic characteristics, environmental attitudes, and information profiles among the relevant variables for the analysis.

Following previous literature, we consider socioeconomic characteristics and informational factors as variables that can influence price misperception. As reported by García-Valiñas et al. (2021), price perception studies may suffer from selection bias when using household survey data because the decision to answer questions related to price information may be influenced by unobservable characteristics, such as survey respondents' propensity to keep and consult their water bill. Our working hypothesis is that households that provide their actual bill may be more informed and, consequently, show lower misperception levels.

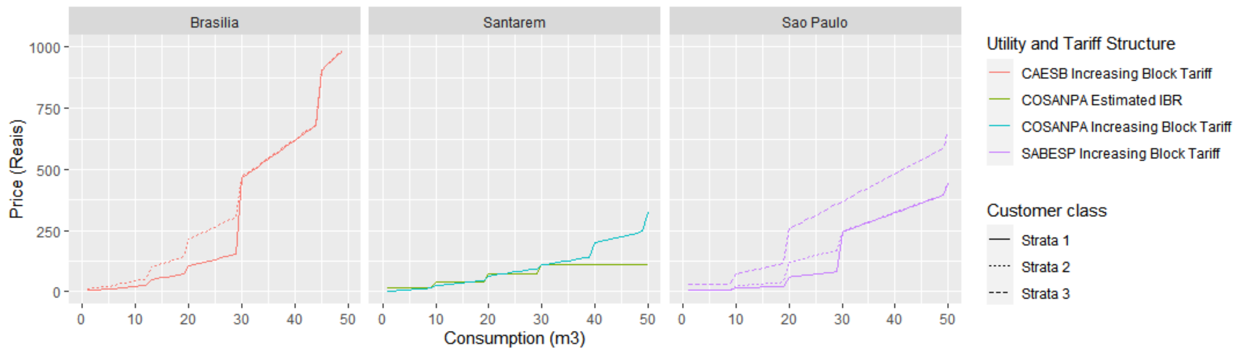
To the best extent of our knowledge, there are no studies that analyze price misperception in the water sector in developing countries, where there may be other factors also affecting this bias, such as common concerns related to the quality of the service (Andrés et al., 2021). In the absence of accurate price information, we hypothesize that consumers may form judgements and assumptions about price based on their perceived water quality. In particular, we believe that consumers who perceive water quality as low, may think water is expensive for the service they receive.

3. Context of the study

There are several institutions involved in water policy design and implementation in Brazil (OECD, 2015). At a national level, 84% of the population has access to water and 54% to sanitation (SNIS, 2020). The Brazilian constitution delegates the provision of drinking water and sanitation services to municipalities, but most states have a state-owned company. These state-owned companies provide the bulk of water and sanitation services in Brazil, servicing around 72% and 65% of the total served urban population, respectively. Water and sanitation services are also provided through municipalities and municipal companies (22% and 28% of the population serviced, respectively) and through private sector companies (5% and 7% of the population serviced, respectively) (Pimentel and Capanema, 2018).

The regulatory role of setting tariffs belongs to local governments, though it is often delegated to the State or to an inter-federative consortium (Sampaio and Sampaio, 2020). Tariff pricing structures vary in complexity from simple flat tariffs to more complex volume-based structures (e.g., Increasing Block Tariffs (IBT) and Volume Differentiating Tariffs (VDT)). Most cities in Brazil use some variation of IBTs, wherein households that use more water pay more per cubic meter. Though tariff structures do not have a fixed charge, they generally set a minimum consumption volume (often 10 m^3). Subsidies are the primary economic instrument for improving financial accessibility to water and sanitation services. They are usually offered based on social conditions or geographic location and are usually funded through cross subsidies at the municipality, customer type or block tariff level. That is, there is cross-subsidization both between municipalities and within municipalities. In most tariff structures in Brazil, residents are divided into two groups, Regular Residents and Social Residents, with the latter having subsidies built into their tariff structure (Narzetti and Marques, 2020).

Figure 1: Tariff structures in selected cities (Brasilia, Santarem, and Sao Paulo)[1]



Source: authors' own elaboration based on data compiled from publicly available Brazilian water utilities tariff information, 2021

As a result, water tariffs vary widely, depending on location, socioeconomic factors, the local tariff structure and consumption. Figure 1 shows the tariff structure in three representative cities in Brazil. While the type of structure is IBR (or estimated IBR for non-metered households) in the three cities, there is price variation in consumption levels and in the type of customer classes. The complexity implicit in most water tariff schemes seeking to increase affordability may make it difficult for customers to estimate their water bill, especially in volume-based tariff structures.

The perception of service quality can impact water bill perception. The quality of water services varies widely throughout Brazil, with some areas experiencing semi-regular service disruptions and water quality perception varying significantly (LAPOP, 2019). The perceived quality of water delivered also affects performance perception. In Brazil, quality standards for water providers are established in Consolidation Ordinance No. 5 of 2017, which sets limits for physiochemical parameters and certain contaminants (Chaves Fortes et al., 2019). Adherence to these standards and the risks resulting from water quality issues are evaluated by the National Program for the Surveillance of Drinking Water Quality (VIGIAGUA), through the Secretary of Health Surveillance of the Ministry of Health (Perez et al., 2021). The VIGIAGUA program includes a database on drinking water quality, The Drinking Water Quality Surveillance Information System (SISAGUA), which provides the government with data for the management of health

[1] The customer classes are ordered from low (strata 1) to high (strata 3) income levels.

risks associated with the supply of drinking water (Oliveira et al., 2019). SISAGUA contains control data submitted by service providers and municipal governments, and surveillance data submitted by state Health Ministries. Despite these control mechanisms, perception of water quality remains poor and evaluations of tap water quality have revealed that it may not be just a perception problem (Garcia et al. 2018; Berendonk Handam et al., 2020).

Water service providers can also submit their quality data to the Federal Government's National Sanitation Information System (SNIS), run by the Ministry of Cities National Environmental Sanitation Department, which collects water and sanitation data annually with the objective of maintaining data on the quality of water supply service provision (Oliveira et al., 2019). Submission to SNIS is not mandatory, however, regular submission is a requirement for obtaining financial resources from the Ministry of Regional Development's investment programs, including the PAC - Growth Acceleration Program (SNIS, 2020). The non-mandatory nature of reporting may suggest that the database is less likely to contain data from low-performing service providers, a possibility further investigated in this paper.

4. Empirical strategy

Following Section 3, bill misperception is modeled as a function of perceived water quality indicators, information factors and socioeconomic characteristics. However, to identify the key determinants affecting bill misperception, we first need to address two main issues. First, bill misperception and perceived water quality may be influenced by unobservable characteristics. Consequently, perceived water quality may be correlated with the error term, and therefore, we need to control for this potential endogeneity problem. Second, the respondents' decision to provide the actual bill occurs on a voluntary basis in our sample, and therefore, those who choose to provide their bill may share specific unobservable characteristics that distinguish them from those who do not report it. That is, information on actual water bill is missing because of a selection process and this may result in sample selection bias (Centorrino *et al.*, n.d.) that we also need to control for.

To address the issues presented beforehand, we consider a sample selection model as in Vella (1998) adapted to include endogeneity in one of the explanatory variables:

$$Bill\ misperception_i^* = X_i^{'}\beta + Perceived\ taste'_i\theta + \varepsilon_i \quad (1a)$$

$$Bill\ reported_i^* = \widetilde{W}_i'\gamma + \eta_i \quad (1b)$$

$$Perceived\ taste_i^* = \widetilde{W}_i'\delta + u_i \quad (1c)$$

$$Bill\ reported_i = 1\ if Bill\ reported_i^* > 0;\ 0 \text{ otherwise} \quad (1d)$$

$$Bill\ misperception_i = Bill\ misperception_i^* \times Bill\ reported_i \quad (1e)$$

$$Perceived\ taste_i = 1\ if Perceived\ taste_i^* > 0;\ 0 \text{ otherwise} \quad (1f)$$

where (1a) is the equation of primary interest, and (1b) and (1c) are the reduced form for the latent variables capturing sample selection and endogeneity of one of the explanatory variables in (1a). $Bill\ misperception_i^*$ is a latent endogenous variable with observed counterpart $Bill\ misperception_i$ for household i; $Bill\ reported_i^*$ is the latent process related to the selection mechanism, with associated indicator function $Bill\ reported_i$, denoting whether household i provided the water bill and, therefore, the level of bill misperception is observed. $Perceived\ taste_i^*$ represents the latent process related to households' underlying water quality perception, with observed counterpart $Perceived\ taste_i$. The relationships between the abovementioned latent and observed variables are shown in (1d), (1e) and (1f). X_i is a vector of exogenous explanatory variables, and $\widetilde{W}_i$ contains a vector of instruments W_i and X_i;[2] β, θ, γ and δ are parameter vectors to estimate. ε_i, η_i and u_i are zero-mean error terms with $E(\varepsilon_i|\eta_i) \neq 0$, $E(\varepsilon_i|u_i) \neq 0$ and $E(\eta_i|u_i) \neq 0$.

[2] While many theoretical models impose that $\widetilde{W} = X$, the inclusion of additional variables W in the first step may be relevant for identification purposes in the second step, as constraining $\widetilde{W} = X$ and relying on the nonlinearity in the IMR for identification may not be satisfied, resulting in unreliable second step estimates and inflated standard errors (Vella, 1998).

We simultaneously estimate the system of equations by Maximum Likelihood using the Conditional Mixed Process (CMP) by Roodman (2011),[3] which is suitable for estimating our simultaneous equation model as it satisfies the following two conditions:

- Recursivity: the equations can be arranged in a way that the matrix of coefficients of the endogenous variables in one another's equations is triangular.
- Full observability: the endogenous variables on the right-hand sides of the equations appear as observed. This condition also applies in the case of a dummy endogenous variables such as *Perceived taste,* included in equation (1a), since it is the observed counterpart and not the latent variable the one included on the right-hand side.

The CMP framework allows to jointly estimate a system of equations with linkages among their error terms. Moreover, the use of this Maximum Likelihood approach to estimate the equations as a system rather than as a two-step or three-step estimator results in efficiency gains.

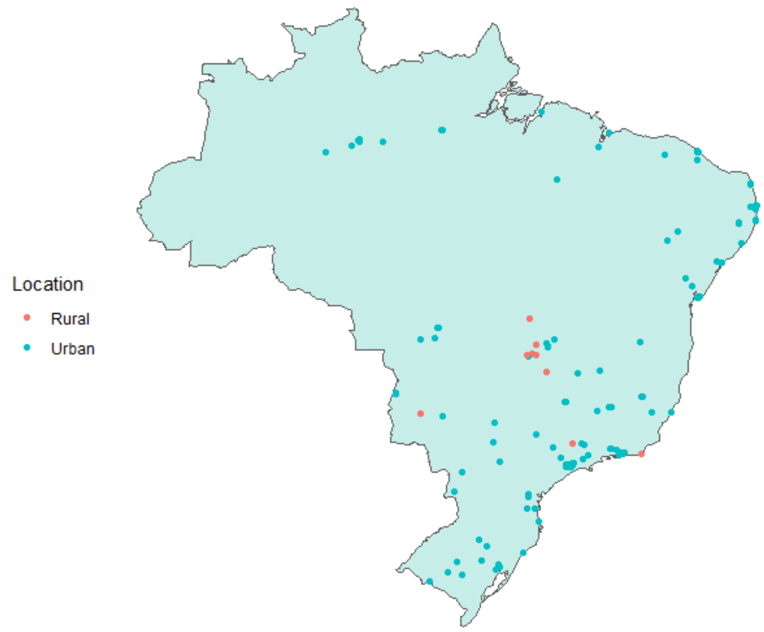
5. Data and Variables

Our database comprises several sources of information. First, a household survey in Brazil designed by the Water and Sanitation Division of the InterAmerican Development Bank (IDB). Second, data on water utilities reporting to the Brazilian National System on Sanitation Information (henceforth referred as SNIS, the Portuguese acronym for Sistema Nacional De Informações Sobre Saneamento). Last, information on municipal GDP per capita obtained from the Brazilian Institute of Geography and Statistics (IBGE) for 2018, that is, the year before the survey data collection.

The household survey collected information on water bill, quality and perception on both bills and quality from 1,504 respondents (111 distribution centers and 1,393 households) throughout Brazil between August 1 and August 31, 2019, resulting in a representative sample at the urban and rural level. Figure 2 shows the geographic distribution of survey respondents.

3 The Stata routine CMP has been used in this study.

Figure 2: Brazil Household Water Survey respondent locations



Survey respondents were asked about perceived water bill, defined as the amount they believe they paid in the last billing period; and perceived water quality, measured as their perception on water clarity and taste based on a 5-point Likert scale. Additionally, respondents were asked to voluntarily provide a copy of their most recent water bill[4] and to allow to perform a test on water samples obtained from a tap directly connected to the distribution system and collected during the interview (Gómez Vidal et al., n.d.). The survey also includes questions about housing characteristics and metadata such as the date and time of the interview, interview duration and the location of the interview.

Regarding the second source of information, the Federal Government's National Sanitation Information System (SNIS) collects water and sanitation data annually from water and sanitation service providers through a voluntary data submission process. Service providers report financial, economic, managerial and water quality information to

[4] Respondents may not provide their water bills due to trust issues, but also because they are not able to. The latter case would be when consumers do not keep their bills or when they opt for paperless alternatives. It is expected that this case would take place more often in higher income households because the water bill represents a very low share of their monthly expenses or because they have a propensity to rely on electronic billing due to more access to mobile and fixed internet.

the SNIS. For 2018,[5] SNIS contains data for 5,146 municipalities, representing 92.4% of municipalities in Brazil, and contains service data for an urban population of 173.2 million, or 98.1% of the urban population in Brazil. Despite this high level of representativeness, the voluntary nature of data submission indicates that selection bias could be a concern when using SNIS data, an attribute of the data that is used by this study as an indicator of transparency.

Last, the Municipal Gross Domestic Product dataset is produced by the IBGE in partnership with State statistical agencies, state government Secretariats and the Superintendent of the Manaus Free Trade Zone. It contains municipal-level data on economic activity, as well as GDP and GDP per capita from 2010-2018.

Merging data from these three sources resulted in a cross-sectional database. Our main variable of interest, *Bill Misperception*, is constructed as the ratio of perceived water bill to actual water bill, which is obtained from the copy of the most recent water bill provided by survey respondents. Therefore, the indicator is equal to 1 when these two variables coincide, and greater (less) than 1 if the consumers overestimate (underestimate) their water bill.

As explanatory variables we consider *Perceived Taste* as a proxy indicator of perceived water quality. This indicator is based on an ordered categorical variable measured on a 5-point Likert scale with possible answers: Very Bad, Bad, Regular, Good and Very Good. Since it would not be correct to use interval categories as if they were values of a continuous variable, one could construct four binary indicators for each of the ordered categorical perceived water variable. However, as noted in Section 3, perceived water quality may be endogenous, and we do not have enough sample variability to correct for the potential endogeneity of all the resulting binary indicator. Instead, we simplify our original ordered categorical perceived taste variable into a binary indicator that compare households reporting substantial water quality issues (those falling in the two lowest categories) and those stating at least a regular water quality service (those in the three highest categories).

[5] This study uses 2018 data from the SNIS Historical Series to identify the service providers reporting to SNIS.

As information factors we consider a proxy for response certainty, *Time questionnaire,* measured as the time in seconds spent answering the questionnaire. We also include *Individual meter,* a dummy variable that takes value 1 if the household has an individual meter, and therefore it is billed based on their actual consumption level, and 0 otherwise. While consumers who have an individual meter receive more accurate consumption information, it is important to note that they will experience monthly fluctuations in their water bill, as opposed to those households whose consumption is not metered and therefore, their bill is constant over time, the only exception being changes in water tariffs defined by the regulator.

To account for socioeconomic characteristics, we include *GDP per capita* at municipal level; *Independent house,* a dummy variable that takes value 1 for independent house and 0 otherwise; *Paved street,* a dummy variable taking value 1 if the street where the house is located is paved and 0 otherwise; *HHS,* the number of people living in the house; and *Urban*, a dummy variable taking value 1 if the survey respondent lives in an urban area and 0 otherwise.

Regarding the selection equation, the dependent variable is a binary indicator taking value 1 if the respondent voluntarily provides a copy of her most recent water bill and 0 otherwise. As additional variables, i.e., variables excluded from the main regression, we include two proxies for trust in the interviewer since it may have an impact on the likelihood to respond to sensitive requests such as providing the water bill. Specifically, we include a dummy variable, *Recorded,* identifying whether the interview was recorded or not, and two dummy variables controlling for neighboring effects, following the literature that observes significant impacts of neighbors' experiences on program participation (Groves, 1992; Pérez-Urdiales and Baerenklau, 2019b). In this sense, we consider the number of prior interviews per census sector, *Prior neighborhood interviews*.

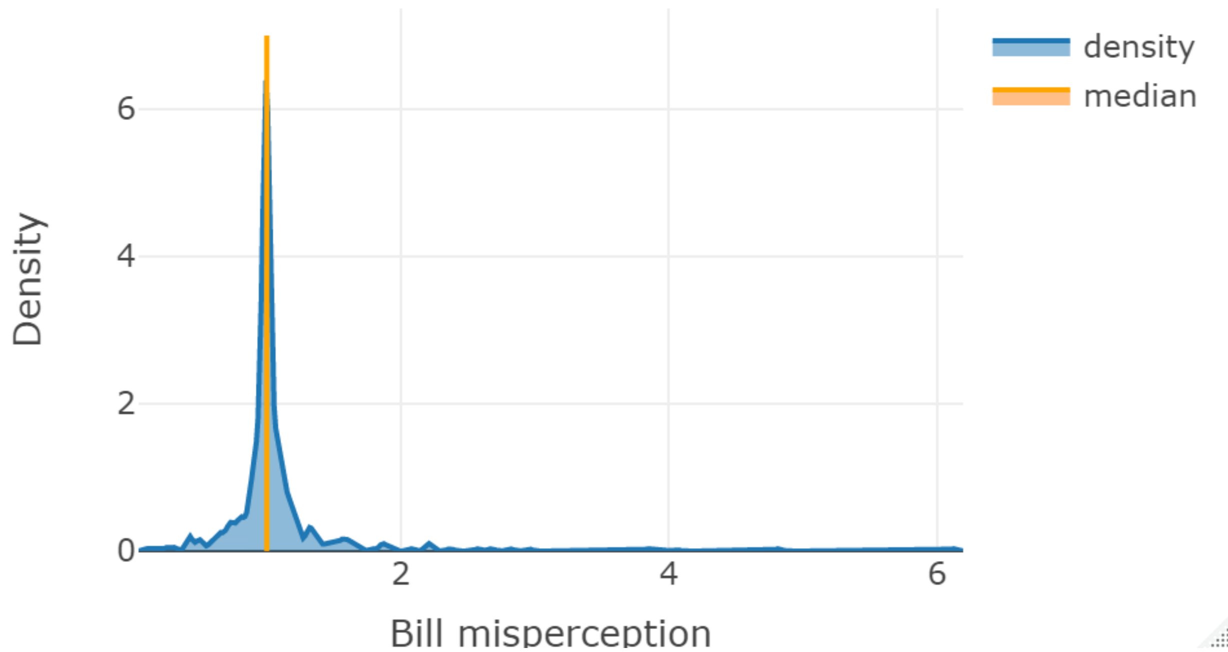
In terms of the instruments in the equation to control for the potential endogeneity of perceived taste, we consider common factors seen in the literature that may influence the perception of drinking water quality. As objective proxies for drinking water organoleptics, i.e., sensorial information from taste among others (Franca Doria, 2010), we include *Chlorine index*, which is a variable computed based on the water samples taken during the interview. We also include a binary indicator that takes value 1 if the water service provider reports water and sanitation data to the SNIS, as a measure of trust in the water companies (Franca Doria, 2010), and its interaction with the chlorine variable to control for the potential incremental effect of organoleptics conditional on water service providers reporting to the SNIS

As can be seen in Table 1, the representative household in the sample overestimates their water bill by 7%. The distribution of *Bill misperception*, presented in Figure 3, shows that most households are relatively well-informed as they bunch around 1, i.e., the value where perceived water bill is equal to actual water bill, which is also the median. However, it is important to note that this variable is only computed for households who provide their actual water bill, which represent 48% of the sample, as shown by the mean of *Bill provision.* Given that we suspect that our sample suffers from selection bias since households providing their bill may be better informed about prices, quantity of water consumed and total bill paid, the observed *Bill misperception* may underrepresent the actual level of misperception. To further explore this hypothesis, in Table 2 we show a difference in means test of the perceived water bill comparing households who report their bill with those who do not.

Table 1: Descriptive Statistics

	Mean	**Std Dev**	**Min**	**Max**	**Source**
Bill misperception	1.07	0.46	0.11	6.13	Brazil Household Water Survey 2019
Endogenous variable					
Perceived taste	0.71	0.45	0.00	1.00	Brazil Household Water Survey 2019
Selection Indicator					
Bill provision	0.48	0.50	0.00	1.00	Brazil Household Water Survey 2019
Instruments for Perceived taste					
ReportSNIS	0.49	0.50	0.00	1.00	SNIS
Chlorine Index	0.78	0.63	0.00	2.50	Brazil Household Water Survey 2019
Chlorine Index x ReportSNIS	0.35	0.58	0.00	2.50	
Additional variables in the selection equation					
Recorded	0.85	0.35	0.00	1.00	Brazil Household Water Survey 2019
Prior neighborhood interviews	5.56	3.65	0.00	23.00	Brazil Household Water Survey 2019
Exogenous variables					
Time questionnaire	1.31	14.25	0.26	533.83	Brazil Household Water Survey 2019
Individual Meter	0.84	0.37	0.00	1.00	Brazil Household Water Survey 2019
GDP pc	34.69	18.85	6.96	94.08	IBGE
Independent house	0.96	0.19	0.00	1.00	Brazil Household Water Survey 2019
Paved Street	0.93	0.25	0.00	1.00	Brazil Household Water Survey 2019
HHS	3.38	1.62	1.00	12.00	Brazil Household Water Survey 2019
Urban	0.91	0.28	0.00	1.00	Brazil Household Water Survey 2019

Figure 3: Distribution of *Bill misperception*



In the absence of a selection problem, one would expect no significance difference in terms of the mean perceived water bill between these two groups. However, the result of the test rejects the null hypothesis of equal means at the 1% significance level. Households who do not provide their water bill on average report a water bill 30% higher than households who provide their water bill. This result supports our intuition that *Bill misperception* would be higher if we could account for households that do not provide their water bill.

Table 2: Difference in means test: *Perceived bill* by *Bill provision*

	Households reporting water bill	Households not reporting water bill	t-test	p-value
Perceived bill	78.89	102.31	-3.32	0.00

Regarding water quality perception, we observe that 71% of the households in our sample report regular to very good perceived water taste. The relationship between this indicator of perceived water quality and *Bill misperception* is not evident, as seen in Figure 4. Most of the observations show values around 1 of *Bill misperception* regardless of the categories of perceived water taste. This intuition is confirmed by a difference in means test that cannot reject the null hypothesis of equal mean *Bill misperception* between the perceived water taste categories. This lack of apparent relationship between *Bill misperception* and *Perceived taste* suggests the need for a more complex multivariate analysis.

Figure 4: Distribution of *Bill misperception* by *Perceived taste*

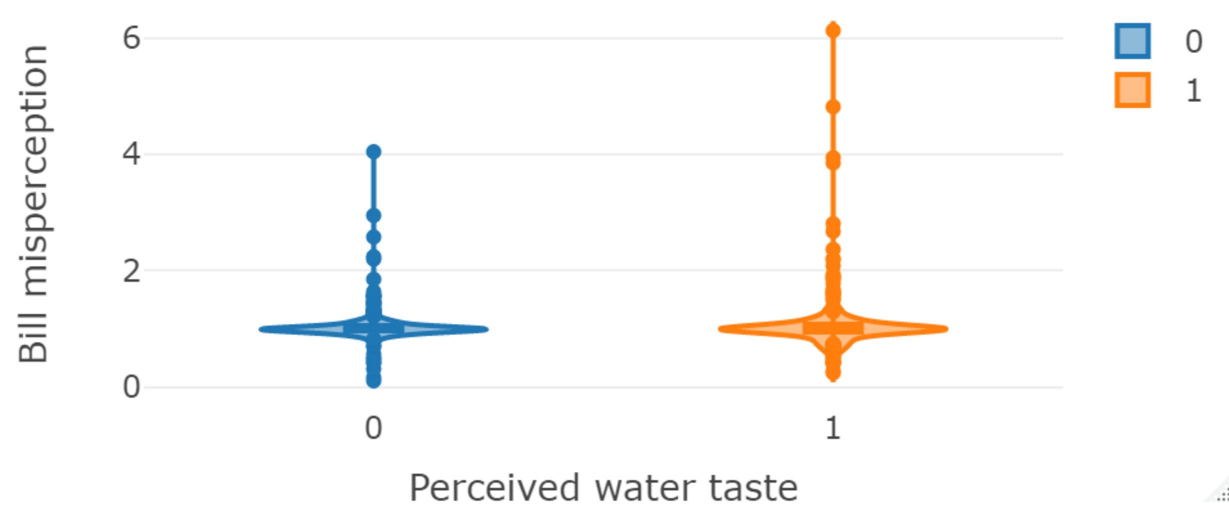


Table 3: Difference in means test: *Bill misperception by Perceived taste*

	Households reporting bad and very bad perceived water taste	Households reporting regular to very good perceived water taste	t-test	p-value
Bill misperception	1.06	1.07	-0.33	0.74

6. Results

Table 4 shows the results of the *Bill misperception* model. For comparison purposes, we also report the results of an OLS model in Column 1, that is, the model assuming exogeneity of *Perceived taste* and no sample selection bias. In this case, we find that the coefficient of *Perceived taste* is not significant. Columns (2), (3) and (4) show the results of the system of equations analyzing *Bill misperception* while controlling for sample selection bias and the endogeneity of *Perceived taste*. The correlations between the error terms, denoted by $\rho_{\varepsilon\eta}, \rho_{\varepsilon u}$ *and* $\rho_{\eta u}$, are statistically significant, confirming the hypothesis of the presence of the abovementioned issues. Focusing on ρ_{12}, its negative sign implies that there are unobservable factors that are negatively affecting *Bill misperception* and positively influencing the probability of providing the water bill. That is, there exists an underestimation of the actual bill misperception: observed *Bill misperception* is lower on average than actual *Bill misperception*. Households with lower levels of misperception tend to provide their water bill and, therefore, become observed *Bill misperception*. As reported in Section 4, observed *Bill misperception* in our analysis is on average above 1, i.e., perceived water bill is higher than actual water bill for households providing the bill. This result confirms our hypothesis that those households not reporting their water bill are less informed and tend to have a more inaccurate perception of water bills, resulting in an overestimation of the amount they pay for water.

Next, we focus on the estimation of the probability of providing the water bill to control for sample selection bias (Column 2). Among the variables related to trust in the interviewer, *Prior neighborhood interviews* has a significant and negative effect on the probability of providing the bill. That is, the greater the number of prior interviews within the census sector, the lower the probability that the respondent provides sensitive information such as the actual water bill. Regarding the remaining variables, which as noted above are the exogenous ones in the main model aiming at explaining *Bill misperception*, the coefficient of *Individual meter* is positive and significant. A possible explanation for this could be that metered consumers tend to keep their bills, since their monthly bill varies month to month reflecting their actual consumption, whereas, unmetered consumers tend to pay a fixed amount, independently of consumption levels, and therefore, may not feel necessary to keep their water bills. The coefficient of *GDPpc* is negative and significant, which may be in line with the previous effect since households in high income municipalities could tend to not have their water bills either because they do not keep them or because they rely on paperless billing. Moreover, the coefficient for *HHS* is also negative and significant. Respondents living in municipalities with higher GDP per capita, belonging to larger households and not having an individual meter installed in the house are less likely to provide the information about the water bill. These results are similar to those in García-Valiñas et al. (2021), who find that a negative effect of household size on the probability of providing an estimate of the water bill, and a positive one of variables indicative of the level of knowledge about the water bill and consumption that could relate to *Individual meter*, such as knowledge of the supplier's webpage or the type of tariff structure.

Column 3 reports the results for the perception of water. While the *Chlorine Index* and *ReportSNIS* do not have a significant effect on the probability of perceiving water taste as good or higher, the interaction between these variables does have a significant effect. Households served by water companies that report to the SNIS, which is a measure of transparency in terms of water quality information, are more sensitive to issues of water chlorine, resulting in a negative effect on their perception. Last, socioeconomic characteristics such as *GDPpc* and *Individual meter*, have a positive and significant effect on the probability of perceiving good or higher water taste. A similar income effect has also been found in previous studies (Grondin et al., 1995; Grondin and Levallois, 1999).

Last, the results for the *Bill misperception* estimation are reported in Column 4.[6] First, we consider our main hypothesis that perceived water quality may influence consumers' assumptions about how much they pay for water. Our results show that *Perceived taste* has a negative and significant effect *on Bill misperception*, i.e., the ratio of perceived water bill to actual water bill. That is, households perceiving their water taste as bad or very bad tend to also report higher perception of water bill with respect to their actual bill. One possible explanation for this result is that consumers are perceiving their water bill as too high for the water service they receive. It is important to note that consumers who perceive water quality as bad or very bad may have to resort to more expensive substitutes for piped water such as bottled water or tanks, which may also affect their perception about how much they pay for water.

Regarding information factors, *Time questionnaire* has a negative and significant effect on *Bill misperception,* indicating that those respondents who take more time to answer the questionnaire are more likely to have lower values of the ratio of perceived water bill to actual water bill. One potential explanation is that respondents will tend to overestimate their water bill when they do not take sufficient time to meditate on their monthly budget. The coefficient of *Individual Meter* is positive and significant, implying that households whose consumption is metered individually, tend to report higher *Bill misperception.* This result may be due to the fact that the water bill fluctuates monthly based on consumption for households with an individual meter, whereas non-metered households are usually charged a fixed monthly amount, i.e., constant over time and therefore, easier to remember. *GDPpc* has a positive and significant effect on Bill misperception, which may be capturing differences such as wealthier households not paying attention at the actual bill as it represents a small proportion of their income or as they access the bill online. *HHS* has a positive effect on *Bill misperception.* That is, the

[6] We perform an overidentifying restrictions test by regressing the residual of the *Bill misperception* equation, ε_i, on the instruments and the exogenous variables, and we compute a J-statistic with a χ_3^2 distribution under the null hypothesis that all the instruments are orthogonal to the residual (Angrist and Pischke, 2009). The resulting J-statistic is 6.25, with a p-value of 0.101, hence we do not reject the null hypothesis. That is, the instruments are not correlated with the error term.

greater the number of household members the higher the ratio of perceived water bill to actual water bill. Since monthly household water consumption depends on the individual behavior of its members, the larger the household, the higher total consumption, the more difficult to correctly provide an estimation of their water bill, leading to higher bill misperception ratios. The coefficient of *Urban* is negative and significant, which may be due to urban houses being smaller and with fewer and more efficient water-using devices, leading to a more constant water consumption and bill over time. Moreover, this coefficient could also capture other differences usually associated with the distinction between urban and rural, such as the level of education.

Table 4: Estimation results

	OLS model	System of Equations		
	(1)	*(2)* *Bill provision*	*(3)* *Perceived taste*	*(4)* *Bill misperception*
Prior neighborhood interviews		-0.0208*	-0.00466	
		(0.0124)	(0.00784)	
Recorded		-0.0331	0.251*	
		(0.125)	(0.132)	
ReportSNIS		0.159	0.0895	
		(0.221)	(0.145)	
Chlorine index		-0.0462	-0.0447	
		(0.100)	(0.0890)	
Chlorine index x ReportSNIS		-0.0701	-0.230*	
		(0.139)	(0.136)	
Time questionnaire	-0.0455***	0.0522	0.00164	-0.0475***
	(0.0165)	(0.0742)	(0.00120)	(0.0146)
Individual meter	0.0896	0.752***	0.236*	0.135*
	(0.0666)	(0.189)	(0.142)	(0.0798)

GDPpc	-0.000540	-0.00913*	0.0162***	0.00376***
	(0.000655)	(0.00518)	(0.00373)	(0.00145)
Independent house	-0.000841	0.265	-0.116	-0.0597
	(0.0516)	(0.232)	(0.187)	(0.0744)
HHS	0.0294*	-0.0534*	0.0152	0.0285**
	(0.0156)	(0.0298)	(0.0230)	(0.0129)
Paved	-0.0760	0.183	-0.0429	-0.0324
	(0.169)	(0.214)	(0.155)	(0.142)
Urban	-0.159**	0.0991	-0.287*	-0.239***
	(0.0701)	(0.190)	(0.152)	(0.0826)
Perceived taste	-0.00549			-0.699***
	(0.0394)			(0.112)
Constant	1.172***	-0.624	0.0576	1.614***
	(0.186)	(0.507)	(0.338)	(0.210)
Observations		1,388	1,388	1,388
$\rho_{\varepsilon\eta}$				-0.1401
p-value				0.056
$\rho_{\varepsilon u}$				0 .8402
p-value				0.000
$\rho_{\eta u}$				-0.1747
p-value				0.002

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

Clustered standard errors by municipality reported between brackets

As explained in Section 5, our *Bill misperception* indicator is a continuous variable taking values equal to 1 if the perceived water bill equals the actual water bill and values > (<) 1 if the perceived water bill is greater (lower) than the actual water bill. Given that it is a continuous variable, our model identifies the changes in this ratio caused by changes in a determinant, i.e., our model does not control for asymmetric effects in the sense of different impacts depending on whether the survey respondent under or overestimates the water bill. To better understand the impact of key determinants on *Bill misperception*, we compute the predicted ratio of perceived water bill to actual water bill and the level of misperception expressed in R$ for different scenarios. We focus on two variables that can be affected by public policies, *Perceived taste* and *Individual meter*; and we consider the following scenarios:

- Scenario 1: in this scenario, *Perceived taste* is set to 0 for all survey respondents, ceteris paribus. That is, all households perceive water taste as bad or very bad.
- Scenario 2: we consider that a policy aims at improving households' perception on taste, and therefore, in this scenario, *Perceived taste* is set to 1, i.e., households' perceived water taste ranges from regular to very good.
- Scenario 3: in this scenario, we assume that no household has an individual meter, i.e., *Individual meter* is set to 0 for all survey respondents.
- Scenario 4: we consider a policy to foster the installation of individual meters, leading to the variable *Individual meter* being equal to 1 for all households.

Table 5: Predicted *Bill Misperception* under different scenarios

Scenario	$\widehat{Bill\ Misperception}$	*Misperception in R$*
Perceived taste = 0	1.59	45.43
Perceived taste = 1	0.89	-8.71
Individual meter = 0	0.97	-1.95
Individual meter = 1	1.11	8.51

The simulations in Table 5 show that policies successfully changing water quality perceptions have potentially important effects on the level of Bill misperception. We observe that, based on our estimation results, if all households perceived water taste as bad or very bad, on average, they would overestimate their monthly water bill by R$45.43, i.e., more than 50% of the average water bill. However, if all households perceived water taste as regular or better, they would slightly underestimate their monthly water bill by R$8.71. While some degree of misperception would still exist, it would be strongly reduced.

The level of misperception for the scenario in which we assume that none of the households have an individual meter is relatively low, representing an average underestimation of less than R$2 per month. However, if we consider a scenario in which all households are equipped with an individual meter, the degree of misperception would increase, implying a monthly overestimation of R$8.51. As noted above, we believe this result may be due to the monthly bill volatility experienced by households whose consumption is metered. In this context, efforts could be focused on providing consumers more information about their monthly water consumption over the year to predict their bills better.

7. Conclusions

This study is the first, to the extent of our knowledge, to explore the determinants of water bill misperception in a developing economy. To that end it relies in a unique survey implemented in Brazil in 2019. A preliminary data analysis reveals that households who report their water bill are generally well-informed as they have low levels of bill misperception. However, after controlling for the selection bias caused by survey respondents providing their bills voluntarily, households tend to overestimate the amount they pay for water.

Our findings show that, beyond the usual informational and socioeconomic factors considered in the literature, perceived water quality is a relevant determinant of the degree of bill misperception when the latter is analyzed in the context of a developing country where water quality may be perceived as inadequate. We find that households who state that water taste is bad or very bad show a higher level of bill misperception. This result may indicate that households who perceive bad or very bad water quality tend to substitute piped water for more expensive alternative water sources such as bottled water and tanks, resulting in a higher perception of monthly utility billed water expenses. Perceived water taste is significantly impacted by the interaction between objective sensorial information on chlorine and participation of the water service provider in information reporting to the SNIS. Households' water quality perception is more sensitive to chlorine if they are served by a provider that regularly reports its water quality. Moreover, we find that, on the one hand, households with individual meters are more likely to provide their water bill, and therefore, may be more informed. On the other hand, households with individual meters have higher levels of bill misperception, which may be due to varying monthly water bills as opposed to constant monthly charges paid by non-metered consumers. Our results are supported by the simulation of different policy scenarios.

From a policy perspective, our analysis suggests that bill misperception may be greater than observed through dedicated household surveys. Considering that 52% of the sample we use in this paper does not voluntarily provide a copy of the water bill and that group report 30 % higher water bills than households that show their water bill, a substantial proportion of the population may decide their consumption based on inaccurate information, which results in consumer welfare losses and ineffective water pricing policies. Since our results show that households with an individual meter (i.e., with non-constant monthly water bills) tend to show higher bill misperception, policies aimed at increasing the number of households with individual meters could be accompanied by informational campaigns. Moreover, households who perceive water quality as bad or very bad may also experience higher welfare losses as they decide their water consumption based on higher levels of bill misperception. Given that water quality problems may tend to occur in poorer neighborhoods (Faria *at al.,* 2017), it is important that policymakers ensure and communicate adequate water quality standards to avoid regressive effects.

Further research is needed to understand the effect of bad and very bad perceived water quality in the choices of water sources and the implications it may have in terms of water affordability, as this is relevant information for policymakers aiming at improving the provision of essential public services and fund the upgrades in infrastructure and quality of services through bill collection.

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