

The determinants of two-dimensional service quality in the drinking water sector – evidence from Colombia

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Abstract

Quality of drinking water service is considered in two dimensions: tangibles (measured by sediment, taste, smell, and color) and reliability (measured by service continuity). Using a large and unique household-level dataset, we study important factors that are related to these dimensions in the Colombian drinking water sector. Based on the network design of pumping, purification, and delivery, our main findings are: (1) compared to users who do not receive a subsidy for water consumption, users who receive a subsidy report less reliable service while tangibles of water quality do not show significant difference between the reports of these two types of users; and (2) compared to water supplied by public providers, water supplied by community providers shows worse tangibles, while service reliability does not show significant difference between these two types of providers. These results suggest that Colombia water reform should not only aim to expand service and prompt water usage for the poor, but also strengthen quality control in multiple dimensions.

Keywords: Colombia; Community provider; Consumption subsidy; Drinking water; Service quality; Tangibles

1. Introduction

According to the World Health Organization, nearly 2 million people die each year from diarrheal diseases caused by inappropriate water and sanitation services. Aimed to reduce disease and improve people's livelihood in developing countries, reforms of drinking water service are undertaken to guarantee basic water usage and quality of service. These reforms include providing consumption subsidies on the user side and allowing more providers to supply water service. During the reforms, establishing incentives for improving water quality along several dimensions would motivate utility managers to give

doi: 10.2166/wp.2016.123

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greater attention to maintenance, and upgrades to reduce customer complaints and promote better service quality. The role of the sector regulator is important for the establishment and enforcement of such incentives. The outcomes of these reforms reflect regulatory incentives and the nature of the cross-subsidy scheme.

The Colombian drinking water sector fits the situation discussed above. It applies cross-subsidies to promote water consumption in poor households and allows for the participation of the community provider to expand service to rural areas; however, many households receive low-quality service, reflected in drinking water having high levels of sediment; abnormal color, taste, and smell; and frequent service interruptions (Komives *et al.*, 2005). The Colombian drinking water sector provides an interesting example of a household's basic water usage being enhanced through the reforms of the drinking water sector, while service quality to some households is weakened. Due to the lack of high-quality data, however, there have been very few studies that investigate the determinants of the service quality during the reform.

This research aims to fill the gap in the literature by merging four datasets to empirically explore the factors associated with low-quality service reported during Colombian drinking water reforms. In particular, using the RATER system of service quality measurement (Parasuraman *et al.*, 1994), the service quality in the drinking water sector is considered in two different dimensions: reliability and tangibles¹. Reliability is measured by service continuity and tangibles are measured by whether the water includes sediment or bad taste, smell, or color. We then examine how each quality dimension is affected under the network design of water pumping, purification, and delivery (Figure 1). On the one hand, water tangibles are more related to the techniques, chemicals' expenditure, and administration during the pumping and purification process. Poor tangibles of water are more likely caused by technical and administrative drawbacks on the provider side. On the other hand, given capacity, the failure of reliability is more likely to happen during the delivery process; for example, service is intentionally shut down by the utilities on the user side².

Based on the network design of drinking water service, this paper explores how each quality dimension is related to the following two major factors. The first factor is the type of utility providers. Besides public providers, the Colombian water sector allows the participation of community providers to expand service in rural areas³. A community provider is a community organization that is created to supply water service to members in the community. Both public provider and community provider are required to adopt cross-subsidies, but their ownership and capital structure are different. Public providers are owned by the municipality and their majority share of capital is from the municipal government. In contrast, community providers are mainly owned by the communities and their majority share of capital comes from members of a community. In some cases, these community providers can have some

¹ See Parasuraman *et al.* (1994) for the RATER system to measure service quality in five dimensions: reliability, assurance, tangibles, empathy, and responsiveness. Due to data limitations, this paper considers two of these dimensions in the drinking water sector: reliability and tangibles.

² Local conditions, including collective action and the role of non-governmental organizations, can also have impacts on service quality, but this study did not address such factors.

³ The Colombian water sector has four types of service provider: public, private, municipal, and community. Our user type variable is constructed based on the answers to the survey question, 'Which source is drinking water obtained from?' The only two piped-water options relevant for our study are community provider and public provider. We expect that survey respondents served by private or municipal water utilities are included in the 'public provider' category.

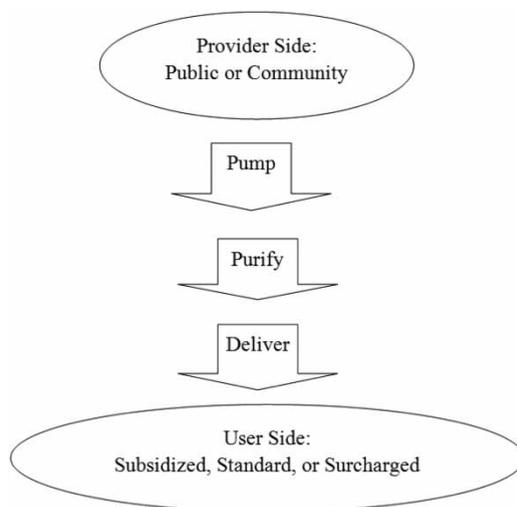


Fig. 1. Network design of water pumping, purification and delivery.

public capital, or have participation of private capital other than members of the community. Compared to public providers, community providers are usually smaller firms, which share a general weakness: lack of support from the local and national governments (Cárdenas, 2012). Specifically, most of them have less advanced operating systems, less effective purification technologies, less qualified human resources, more limited capital investments, and less service experience. These drawbacks affect their performance during the pumping and purification process, so they may deliver water with poor tangibles. Assuming no other incentives exist, however, the utility type will not affect service reliability.

The second factor is whether the user receives subsidies. In practice, Colombian cross-subsidies cause serious financial deficits in utilities. To reduce the total amount of subsidies, utilities can choose to shut off the service frequently to subsidized households to discourage usage⁴. This action can be taken by utilities at very low cost, so it is possible that a financial deficit under cross-subsidy policy induces more service interruption to the subsidized households. Meanwhile, utilities will not weaken the tangibles of water delivered to the subsidized households because the operation cost of this action is relatively high.

The literature on service quality of the drinking water sector does not fully reflect the importance of the sector. Service quality is often taken into account when the performance of water utilities is measured through the use of benchmarking (Berg & Lin, 2008). As pollution becomes a major obstacle to sustainable development, many researchers also use service quality as an important measurement to examine the outcome of regulation or reform in the water sector (Dieperink, 1998; Banadda *et al.*, 2009). Other researchers have noticed the importance of people's perceptions of water quality and tried to find the factors that affect perceptions (de França Doria *et al.*, 2009; de França Doria, 2010).

⁴ The total subsidy amount equals the subsidy rate multiplied by usage; thus, the utility can reduce the total subsidy amount through reducing usage by subsidized users.

However, previous studies rarely broke down service quality into different dimensions for detailed analysis.

This study contributes to the literature in two important ways. First, it is among the first to examine the determinants of two-dimensional service quality (tangibles and reliability) in the drinking water sector⁵. Only a few studies have investigated the factors that are associated with low-quality service in the drinking water sector during service reforms. [McRae \(2015\)](#) shows that in Colombia the subsidy policy deters investment to modernize infrastructure in subsidized areas. [Li & Berg \(2014\)](#) analyze the impact of Colombian cross-subsidies on service quality in the electricity sector and provide empirical evidence that the cross-subsidy system induces utilities to provide lower-quality service to subsidized households than to non-subsidized households. This quality variation is explained by a utility's cost-saving reaction to the financial deficits associated with the subsidy policy⁶. These researchers, however, do not distinguish among the impacts of different quality dimensions. Second, previous research focuses on the effect of private sector participation on infrastructure service ([Marques, 2008](#); [García-Valiñas et al., 2013](#); [Destandau & Garcia, 2014](#)), while ignoring the effect of community provider participation on utility service.

The remainder of the paper is organized as follows. Section 2 introduces the background of the Colombian drinking water sector and its reforms of promoting basic water usage. Section 3 describes the data and summary statistics. Section 4 presents the empirical methodology and quantitative results. Section 5 summarizes the main findings and policy implication.

2. The Colombian drinking water system

The 1991 constitution identified public utilities (including water, electricity, natural gas, and telecommunication) as one of the core services that contribute to the livelihood of the population. The current legal framework of the Colombian drinking water sector was established in the early 1990s. During the water service reform of that time period, two important changes were applied across the country to guarantee safe, affordable, and sustainable water service to the whole of society.

The first change was to increase the participation of service providers in the water sector. The 1991 constitution (Article 365) allowed community providers to participate in public utility sectors, which turned out to effectively improve service coverage, especially in undeveloped areas ([Cárdenas, 2012](#)). Community providers, however, are usually microenterprises, which tend to have less-advanced techniques, weak management (and governance systems), and limited government support. This raises concerns on the service quality that they provide.

The second change was to apply consumption cross-subsidies across the water sector. The Public Residential Service Law 142 and 143 of 1994 laid out the national cross-subsidies system and its geographic targeting scheme in public utility sectors. Created to encourage utility consumption by the poor, the cross-subsidy redistributes natural resources more equally across populations by charging the poor a lower price than other consumers. The system employs a zonal poverty criterion based on a six-level socioeconomic stratification of all neighborhoods, according to the physical quality and surroundings

⁵ See [Tchorzewska-Cieslak \(2007\)](#) and [Boryczko and Tchorzewska-Cieslak \(2013, 2014\)](#) for discussion about service reliability and risk of lack of water supply.

⁶ [Ingenieros y Economistas Consultores \(2006\)](#) finds significant cash-flow deficit caused by the Colombian cross-subsidy policy.

of their dwellings (Gómez-Lobo & Contreras, 2003; Meléndez *et al.*, 2004; Medina *et al.*, 2007)⁷. Up to the year 2003, households were eligible for consumption subsidies of up to 50 percent of the average service cost for their basic consumption⁸ if they lived in dwellings classified as Strata 1, up to 40 percent if they lived in dwellings classified as Strata 2, and up to 10 percent if they lived in dwellings classified as Strata 3. Law 812 of the year 2003 changed the cap for Strata 1 up to 70 percent. Households in Strata 4 pay the standard price, which is equal to the average cost of the providing service. Households in Stratas 5 and 6 pay surcharges of no more than 20 percent of the cost recovery price. The system is designed to internally fund subsidies through surcharges with the remaining deficit funded through government transfers; however, in practice, utilities have serious financial deficits even after the government transfers because too many households receive subsidies^{9,10}. This deficit raises the issue of whether service quality to subsidized households will be reduced. Li (2014) shows that (in theory) when facing financial deficits due to subsidizing the poor, a utility will reduce its deficit through reducing service quality to them¹¹. This is because the lower quality will discourage the poor from consuming the utility service, which effectively reduces the total amount of subsidies. Li & Berg (2014) provide empirical evidence of lower-quality service for subsidized households in the Colombian electricity sector.

The service reform in the drinking water sector contributes to coverage expansion and consumption promotion for poor households, while ignoring the consideration of service quality. This captures attention from both political and academic perspectives.

3. Data

The data used in this study are compiled from four sources: (1) data on the quality of drinking water service from the Living Standard Measurement Survey (Encuesta de Calidad de Vida (ECV), 2008)¹², (2) the municipality-level fiscal performance dataset in 2008, (3) the municipality-level socioeconomic development index in 2008, and (4) 2008 Colombia population data estimated by Departamento Administrativo Nacional de Estadísticas (DANE).

⁷ Under this classification, dwellings in the same strata are spatially connected and located in the same geographic areas. Households in the same strata usually have similar income levels. Home selection rarely happens in practice, for example, rich people rarely live in low strata, because they are not willing to give up nice neighborhoods to lower utility price only.

⁸ The Colombian water sector applies increasing block tariffs and the subsidies are only for the first block of consumption (basic consumption).

⁹ According to the World Bank's report on Colombian economic developments in infrastructure (2004), about 75% of households received subsidies from consuming public utility in 1993; about 87.5% of households received these subsidies in 1997 and this ratio increased to 90.5% in 2003. The cross-subsidy scheme presents a deficit of US\$96.6 million per year in the water sector.

¹⁰ Future research needs to address the issue of how the level of national transfers is determined and the allocation of municipal funds across different sectors. That issue is beyond the scope of this paper.

¹¹ It is also possible that those receiving subsidies do not report substandard service via complaints either due to lack of confidence that remedial action will be taken or out of realization that their subsidized service may be (naturally) lower quality. Given the evidence from the literature, however, this paper focuses on the potential impacts of a cross-subsidy policy.

¹² The Colombian Bureau of Statistics, DANE, carried out this household survey (ECV) every 5 years from 1991 to 2008. After year 2008, DANE undertook it every 2 years (2010 and 2012). From the year 2013, DANE has carried it out annually. However, after the year 2008, these household surveys do not request information regarding water service quality. Thus, the ECV database at the year 2008 is the latest one that provides unique information regarding two-dimensional service quality in the Colombian water sector.

The Living Standard Measurement Survey covers nationwide about 12,000 families in most main municipalities in Colombia. Service quality (reported by the family head) is considered in two dimensions: reliability and tangibles^{13,14}. Following Barrera-Osorio *et al.* (2009), the first dependent variable, service reliability, is constructed based on answers to the ECV survey questions, ‘Is water provided seven days a week?’ and ‘On the days that water does arrive, is it continuous for 24 hours?’¹⁵ We adopt a dummy variable that takes a value of 1 if the household has access to water seven days a week, 24 hours per day. The second dependent variable, tangibles of drinking water, is created based on answers to the ECV survey question, ‘Does the water present the following characteristics? Sediment, bad taste, bad smell, bad color, or none of the above?’ We adopt a dummy variable that equals 1 if the water does not have any of the characteristics listed. This survey also provides data about dwelling stratification (this is used to determine the type of service user), the ownership of a utility (this is used to determine the type of service provider), household demographic characteristics, dwelling ownership, and the family head’s education level.

The main explanatory variables are whether households are subsidized for drinking water consumption and whether households receive water service from community providers. These two factors capture determinants of low-quality service. In theory, when facing a deficit from cross-subsidies, the utility provides frequent service interruptions to subsidized consumers (households living in Stratas 1, 2, and 3) to reduce its deficit. Community providers supply water with poor tangibles, because this type of provider suffers from technological and administrative limitations; of course, it is also possible that revenue from water sales and financial resources available to community providers are less than those of public providers, limiting investments that would achieve better tangibles.

The study uses family-level characteristics to control for the effect of demographic factors on the reported quality. These variables, derived from the ECV survey questions, include family size, dwelling ownership, family head gender, education, and age.

In addition, the study considers three municipality-specific attributes: fiscal dependence of the municipal government on the central government, socioeconomic level, and population density¹⁶. To obtain these municipality-level characteristics, we use the dwelling location to link the service quality dataset to the municipality-level fiscal performance dataset, socioeconomic development index dataset, and population census by hand¹⁷. First, the fiscal performance dataset provides the municipality-level fiscal dependence index, which measures the fiscal support from the central government to each municipal government. Colombia

¹³ dePalencia and Pérez-Foguet (2012) analyze the effect of water service performance on coverage in rural Tanzania. The water service performance is considered in two dimensions: year-round reliability, and perceptions of water (including whether water is clear, colored or salty), which is similar to our paper.

¹⁴ This paper considers service quality at the family level rather than the dwelling level because there can be multiple families living in one residential dwelling unit. Each of these families varies in demographic factors and family characteristics, which may affect the family head’s report.

¹⁵ These two survey questions do not clarify the evaluation period for service interruption. The following survey question that is used to create a variable ‘tangibles of drinking water’ does not clarify the evaluation period either. However, with 12,000 investigated families, water users’ reports are adequate to capture differential perceptions of quality.

¹⁶ As a reviewer suggested, climate and topography may affect reliability and tangibles. Future research needs to incorporate climate-related and topography-related variables.

¹⁷ We manually match the service quality dataset and the other three municipality-level datasets (fiscal performance index, socioeconomic development index, and population census) based on the dwelling locations in the databases. These three datasets contain only municipality-level information, and are merged with the service quality dataset based on each dwelling’s municipality location.

Table 1. Summary statistics.

Variable	Mean	Std Dev	Min	Max	Observations
Independent variable					
Service Continuity	0.7775	0.4160	0	1	9,456
Drinking Water Quality	0.7791	0.4149	0	1	11,838
Dependent variable					
Subsidized	0.9549	0.2075	0	1	11,838
Surcharged	0.0155	0.1237	0	1	11,838
Community Provider	0.2073	0.4054	0	1	9,456
Municipal characteristics					
Transfer/Municipality Income	59.6284	20.7167	11.0422	96.9680	11,709
Population Density	1,097.152	2,015.956	2.2297	14,451.24	11,838
Municipal Socioeconomic Index	77.6209	13.3118	42.4534	94.5252	11,838
Households characteristics					
Female Family Head	0.3160	0.4649	0	1	11,838
Can Read or Write	0.9030	0.2959	0	1	11,838
Family Size	3.7593	1.9497	1	20	11,838
Age	48.1103	15.4120	12	98	11,838
Urban	0.6104	0.4877	0	1	11,838
Rural	0.1493	0.3564	0	1	11,838
Own	0.5417	0.4983	0	1	11,838
Rent	0.2631	0.4403	0	1	11,838
Edu2	0.0006	0.0243	0	1	11,838
Edu3	0.4622	0.4986	0	1	11,838
Edu4	0.2859	0.4518	0	1	11,838
Edu5	0.0313	0.1742	0	1	11,838
Edu6	0.0126	0.1115	0	1	11,838
Edu7	0.0126	0.1115	0	1	11,838
Edu8	0.0454	0.2083	0	1	11,838
Edu9	0.0011	0.0331	0	1	11,838
Edu10	0.0190	0.1366	0	1	11,838

Note: This table shows summary statistics for all the variables used in the main regression. Definitions for all the variables are presented in Appendix Table 1 (available with the online version of this paper).

applies decentralized regulation in the public utility sector, but the central government provides financial support to municipalities if it is necessary. The fiscal support data capture the effect on service quality of the dependence of the municipal government on the central government. Second, the development index dataset provides data on municipal socioeconomic conditions, which is used to control for the municipal heterogeneity in terms of overall public utility service and infrastructure development. The municipalities with the higher index usually have public utilities with higher service quality. Third, population density for each municipality is calculated based on 2008 population data estimated by DANE. Population density may reflect the effect of economies of density, which is crucial in the drinking water sector.

The variable definitions are presented in Appendix Table 1 (available with the online version of this paper) and the summary statistics for key variables are presented in Table 1. We find that by comparing the two-dimensional quality level by user type (subsidized, standard, or surcharged households), the difference in service reliability is larger than the difference in drinking water tangibles on average (Table 2). In contrast, comparing the two-dimensional quality level by provider type (community

Table 2. Two-dimensional quality by users.

	Mean of service reliability	Mean of drinking water tangibles
Subsidized	0.7668	0.7761
Standard	0.9527	0.8200
Surcharged	0.9831	0.8859

providers or public providers), we find that the difference in drinking water tangibles is larger than the difference in service reliability on average (Table 3).

4. Estimation and results

Due to the discrete nature of the dependent variable, the study uses a probit model in the regression analysis. The model is given by:

$$\begin{aligned} \text{Reliability}_{ij} \text{ (or Tangibles}_{ij}) = & \\ & \beta_0 + \beta_1 \text{Subsidized}_{ij} + \beta_2 \text{Surcharged}_{ij} + \beta_3 \text{Community_provider}_{ij} + \beta_4 T_j \\ & + \beta_5 \text{Popdensity}_j + \beta_6 \text{Munsocioeco}_j + \beta_7 FC_{ij} + \varepsilon_{ij} \end{aligned} \quad (1)$$

where the dependent variable is Reliability_{ij} or Tangibles_{ij} which are reported by the family head *i* living in municipality *j*; the independent variables are the user type dummies (Subsidized_{ij} or Surcharged_{ij}) and the provider type dummy (Community_provider_{ij}); the control variables are municipal characteristics, including the transfer from nation to municipality *j*(*T_j*), population density(Popdensity_j) and socio-economic index (Munsocioeco_j) and a vector *FC_{ij}* of family characteristics; finally, ε_{ij} captures the unobservable characteristics of the dwellings.

4.1. Main results

We employ a probit model to estimate the service reliability and drinking water tangibles, respectively¹⁸. The main regression results are shown in Table 4 with several interesting findings¹⁹. First, in the estimation of service reliability (Column 1), the coefficients of subsidized households are negative and statistically different from zero and the coefficients of surcharged households are not significant. This suggests that compared to standard households (the base group), subsidized households receive more interruptions of service, while surcharged households receive a similar frequency service. The difference between subsidized users and surcharged users in perceived service quality is presented in Table 5. The result of a *t*-test suggests that the effect of receiving a subsidy on service reliability is significantly different from the effect of paying surcharges. We also find that the coefficient of community

¹⁸ The correlation between ‘tangibles’ and ‘reliability’ is -0.0978 , which suggests that they are not correlated. Thus, it is necessary to discuss the effects of two-dimensional service quality separately.

¹⁹ Standard errors are adjusted for clustering on city.

Table 3. Two-dimensional quality by providers.

	Mean of service reliability	Mean of drinking water tangibles
Public Provider	0.7983	0.8160
Community Provider	0.6980	0.6571

providers is insignificant (Table 4)²⁰, suggesting that service continuity is similar between community providers and public providers. Therefore, service reliability differs based on user type, but not on provider type. Second, in the estimation of drinking water tangibles (Column 2), we find the opposite results: drinking water tangibles differ based on provider type, but not on user type. The coefficients of subsidized households and surcharged households are not significant, suggesting that tangibles reported by subsidized households or surcharged users are not significantly different from tangibles reported by standard households. The comparison of coefficients (Table 5) shows that in the estimation of tangibles, the coefficient of surcharged households is not significantly different from the coefficient of subsidized households, so under the subsidy policy, drinking water tangibles are similar for these two user types. The coefficient of community water provider (Table 4), however, is significantly negative, suggesting that community providers deliver poorer tangibles of drinking water than public providers do, which is based on households' observation of sediment, bad taste, bad smell, and bad color in drinking water²¹.

To demonstrate the magnitude of user type and provider type on two-dimensional service quality, the marginal effect is presented in Table 6.

These opposite results from estimating service reliability and water tangibles show that reforms of applying subsidy policy and allowing community providers participation affect service quality in different ways. This can be explained by the incentives a utility has for adjusting service quality and their network design of water pumping, purification, and delivery. Frequent service interruptions are more likely related to issues on the user side, while poor tangibles of water are more likely related to issues on the provider side (Figure 1).

4.2. Utilities' incentives and constraints to adjust service interruption

Under the cross-subsidy policy, two theories explain why subsidized users receive a lower quality of utility service. First, poor households' utility consumption level is less elastic to service quality, so providers will decrease their spending and investment on their service to subsidized neighborhoods²². Second, when facing financial deficits as a result of subsidizing the poor, the utilities rationally take

²⁰ The correlation between variables 'subsidized' and 'community provider' is 0.1089, which suggests they are not correlated. Thus, the result on the coefficient of 'community provider' is not driven by the interaction between these two variables. It is useful to address the effect of each of them on service quality.

²¹ One review suggests that we should give attention to economic significance. Although the estimated coefficients of some variables seem large in magnitude, they are considerably smaller in terms of economic significance than the others that are statistically significant.

²² See Laffont and N'Gbo (2000) for a detailed discussion on utilities that reduce service quality to the poor because the poor devote a fixed portion of their income to infrastructure services. Also see McRae (2015) for the estimation of the household-level demand function for infrastructure services.

Table 4. Regression results on two-dimensional service quality.

Variables	Service reliability	Drinking water tangibles
Subsidized	−0.3918** (−0.1593)	0.1085 (0.1126)
Surcharged	0.3039 (0.2794)	0.2070 (0.1385)
Community Water Provider	−0.2222 (0.1512)	−0.4116*** (0.1026)
Transfer/Municipality Income	−0.0031 (0.0054)	0.0016 (0.0041)
Population Density	0.0001 (0.0000)	0.0001** (0.0000)
Municipal Socioeconomic Index	0.0236*** (0.0089)	0.0092** (0.0047)
Female Family Head	0.0080 (0.0386)	0.0695* (0.0400)
Can Read or Write	0.0748 (0.0953)	−0.0382 (0.1028)
Family Size	−0.0291*** (0.0096)	0.0073 (0.0089)
Age	0.0016 (0.0018)	−0.0017 (0.0014)
Urban	−0.2459 (0.1993)	−0.0407 (0.1224)
Rural	−0.5928*** (0.1932)	−0.2768** (0.1169)
Own	−0.0664 (0.0558)	−0.0305 (0.0483)
Rent	0.0349 (0.0589)	−0.0110 (0.0589)
Education Level Dummies	Yes	Yes
Observations	9086	9093
R-squared	0.1069	0.0487

Note: The regressions are run based on the probit model. One dependent variable, ‘service reliability’, is based on answers to the questions, ‘Is water provided seven days a week?’ and ‘On the days that water does arrive, is it continuous for 24 hours?’ (1 = Answer Yes to both questions; 0 = Answer No to either one). The other dependent variable, ‘drinking water tangibles’, is based on answers to the question, ‘Does the water present the following characteristics? Sediment, bad taste, bad smell, bad color, or none of the above?’ (1 = None is observed in the drinking water; 0 = Some is observed). The regressions include 9 dummies for education levels. All variables are defined in Appendix Table 1 (available with the online version of this paper). *Significant at 10 percent level; **significant at 5 percent level; ***significant at 1 percent level.

Table 5. *t*-test of coefficients ‘Subsidized’ and ‘Surcharged’.

	Service reliability	Drinking water tangibles
Subsidized = Surcharged	12.19***	0.81

Note: This table shows the estimates based on the probit model (1) in Table 4. All the variables are defined in Appendix Table 1 (available with the online version of this paper). *Significant at 10 percent level; **significant at 5 percent level; ***significant at 1 percent level.

Table 6. Marginal effects on two-dimensional service quality.

Variables	Service reliability	Drinking water tangibles
Subsidized	−0.0910*** (0.0315)	0.0319 (0.0342)
Surcharged	0.0726 (0.0582)	0.0536* (0.0329)
Community Water Provider	−0.0642 (0.0455)	−0.1271*** (0.0343)
Transfer/Municipality Income	−0.0009 (0.0015)	0.0004 (0.0012)
Population Density	0.0000 (0.0000)	0.0000** (0.0000)
Municipal Socioeconomic Index	0.0065*** (0.0025)	0.0026** (0.0013)
Female Family Head	0.0022 (0.0105)	0.0195* (0.0109)
Can Read or Write	0.0211 (0.0275)	−0.0107 (0.0283)
Family Size	−0.0080*** (0.0028)	0.0021 (0.0025)
Age	0.0004 (0.0005)	−0.0005 (0.0004)
Urban	−0.0645 (0.0506)	−0.0114 (0.0342)
Rural	−0.1899*** (0.0699)	−0.0846** (0.0384)
Own	−0.0182 (0.0153)	−0.0086 (0.0136)
Rent	0.0095 (0.0161)	−0.0031 (0.0167)

Note: This table shows the marginal effects on service reliability and drinking water tangibles, respectively. The marginal effects of dummy variables depend on the discrete change from 0 to 1, while the marginal effects of continuous variables are evaluated at the mean values of the covariates. The results are based on the probit model in Table 4. All the variables are defined in Appendix Table 1 (available with the online version of this paper). *Significant at 10 percent level; **significant at 5 percent level; ***significant at 1 percent level.

action to reduce their loss. They can reduce the total subsidy amount through discouraging the poor's water usage²³. Given the network design of water delivery, both reactions can be achieved at a very low cost through switching off water delivery at selected points. Figure 2 shows the three most common network designs of delivery. The utility can intentionally turn off water delivery at points 1, 2, and 3 to shut down the water supply to subsidized households, which can reduce the utility's spending on service maintenance and the total subsidy amount.

Water pumping and purification, however, are usually conducted through an integrated process, so after these two processes, drinking water that is ready to deliver has a similar chemical and biological

²³ See Li (2014) and Li & Berg (2014) for discussions of quality variation conducted by utilities when facing underfunded cross-subsidy policies.

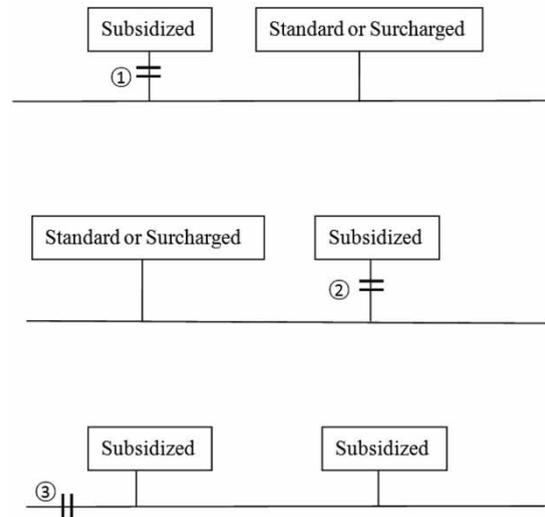


Fig. 2. Water delivery at user side.

standard regardless of the end users. It is very costly to differ the pumping and purification process by user type even if the utility intends to provide drinking water with poor tangibles to the subsidized households because utilities may need to purchase multiple pumps, select a different purification method, and design additional pipelines²⁴. Accordingly, due to the cost constraints, in order to reduce its loss under the cross-subsidies policy, the utility may rationally choose to increase service interruptions to subsidized households rather than change the tangibles of the water itself.

4.3. Utilities' incentives and constraints to control tangibles of water

Compared with public providers, community providers typically have less professional staff, disadvantaged administration and techniques, and less experience; additionally, their pumping and purification processes are weaker than those of public providers. As a result, community providers offer poorer tangibles of water in terms of sediment, color, taste, and smell. Service reliability, however, is less constrained by capital and technical factors given the capacity of plants and pipes. Accordingly, without other incentives, service reliability does not differ based on provider type.

4.4. Other factors associated with service quality

In addition to the main results, we have other important findings regarding municipal factors. First, the coefficient regarding fiscal dependence of the municipal government on the central government (measured by Transfer/Municipality Income) is insignificant in both estimations. The management and regulation of the Colombian water sector can be characterized as having three levels: national,

²⁴ One reviewer inferred from this that it is far more difficult for a utility to deliver differential tangible quality than reliability by user type: tangibles are less elastic to technology.

regional, and local. In large, medium and small capital cities, there is a more decentralized administration, where investment is more local with the central government playing a limited role. However, in the bulk of other smaller cities, the central government plays a key role. These estimation results support the limited role that the central government played in improving service quality during this time frame. Second, the coefficient of population density is significantly positive in estimating the tangibles of drinking water, while insignificant in estimating service reliability. This suggests that economies of density exist in the process of water pumping and purifying, while these do not exist in the process of water delivery given the fixed pipeline. Since economies of scale in distribution are generally strongly dependent on population density, the reasons for the reliability results for the particular topologies that exist in Colombia are unclear. Third, the coefficient of the municipal socioeconomic index is significantly positive in both estimations, suggesting that a municipality with better socioeconomic conditions has, in general, a higher level of service quality in both dimensions: service reliability and water tangibles.

Moreover, the findings on the family characteristics factor provide interesting insights²⁵. First, the coefficient of rural is significantly negative in both regressions, suggesting that the households from dwellings located in rural areas receive more service interruptions and poorer water tangibles. This reflects the disadvantages of drinking water service in rural areas. It is also possible that rural users seldom use water at night, so service interruption is more likely to happen for rural users. Second, we find factors related to human perception may have heterogeneous effects on reported two-dimensional service. Households with large families are more likely to perceive more service interruptions, which represents the negative effects of a crowded family on human perception of service reliability. At the same time, controlling for other factors, households with large families do not report a different level of drinking water tangibles because they are less sensitive to water tangibles than to service reliability. We also find that the coefficient of female family head is insignificant in estimating service reliability, while it is significantly positive in estimating drinking water tangibles. This also reflects the heterogeneous sensitivity to different dimensions of service.

5. Conclusion

In this paper, we use a household-level dataset covering over 100 municipalities in Colombia to study factors that are associated with two-dimensional service quality of the Colombian drinking water sector. Based on the whole network design of drinking water pumping, purification, and delivery, we find that the subsidy policy affects service reliability on the user side, while community utility participation affects tangibles of delivered water on the provider side. More specifically, service reliability for subsidized users is worse than for non-subsidized users, while drinking water tangibles are similar for all types of users. Community providers, however, deliver poorer tangibles of water (in terms of sediment and bad color, smell, and taste) than public providers do, while service reliability from both types of providers is similar. This result is consistent with the nature of the network design: it is low cost to

²⁵ The model without household-level characteristics is re-estimated; its main result shows that the sign of most coefficients remain, but the significance level changes a lot. Given our dependent variable is perceived quality, it is necessary to include household-level characteristics to control for the effect of people's perception on service quality.

modify service on the user side through differentiating continuity; however, technological and administrative procedures determine the tangibles of delivered water on the provider side.

To the best of our knowledge, our paper is one of the first to address the factors affecting two-dimensional service quality in the water sector – partly because of the unique dataset available for Colombia and the geographical basis for subsidies (reflecting the network design). Improving drinking water service, including service coverage, consumption level, and service quality, is crucial for the economic development and livelihood of a society. Reforms, such as subsidies and including more providers, may increase service expansions and encourage consumption in poor neighborhoods, but result in a negative influence on service quality. In developing countries, the regulatory objective of extending service to poor households must be balanced against improving service quality for them. Regulators should consider the costs and benefits of both objectives, and establish incentives to motivate utilities to give greater attention to both of them. Meanwhile, governments should ensure sufficient financial support is provided to utilities when requiring utilities to adopt a cross-subsidy policy. We hope that our study can provide insights for policy-makers and regulators by addressing these negative effects and by distinguishing these effects in terms of different quality dimensions.

Acknowledgements

We are deeply indebted for invaluable guidance and comments from Sanford Berg and Chunrong Ai. Financial support from the Office of Social Sciences and Humanities at the Shenzhen University in China is also gratefully acknowledged. The authors accept responsibility for remaining errors.

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Received 28 May 2015; accepted in revised form 15 December 2015. Available online 28 January 2016