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Reliability perceptions and water storage expenditures: Evidence from Nicaragua

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Reliability perceptions and water storage expenditures: Evidence from Nicaragua

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[1] Storing water at home has become a common practice in many areas with water delivery systems in developing countries. However, little is known about which factors motivate households to expend on water storage devices. Instrumental variable Tobit models are estimated to investigate the relationship between perceptions of water supply reliability and household expenditures on water storage devices in León, Nicaragua. Findings indicate that almost 80% of households use at least one storage device on which they expend an average of 0.87% of their income. Results show that reliability perceptions are the main factor driving household expenditures on storage devices, followed by home ownership and household income. Findings also indicate that reliability perceptions are associated with service performance and assessment of service hours relative to peers.

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1. Introduction

[2] An increasing number of households in developing countries store tap water at home presumably to cope with unreliable water supply. Those households expend considerable amounts of resources acquiring and maintaining water storage devices. *Pattanayak et al.* [2005] show that household expenditures on water storage devices are comparable to costs of other averting behaviors that have received more attention in the literature until now (e.g., in-home water treatment and bottled water consumption). Current expenditures on water storage devices can be considered a lower bound of households' willingness to pay (WTP) for improvements of water supply reliability [*McConnell and Rosado*, 2000; *Pattanayak et al.*, 2005]. Hence, the analysis of those expenditures may be useful for effective design of municipal water policies.

[3] Little is known about which factors motivate households to invest in water storage devices. Identifying those factors requires moving beyond the presumption that households store water at home to cope with unreliable water supplies. Research on averting behavior suggests that, among other factors, subjective perceptions motivate households to implement different measures in order to reduce their exposure to risk and uncertainty. For instance, *Abrahams et al.* [2000] and *Jakus et al.* [2009] show that risk perceptions play an important role in household decisions regarding in-home treatment of tap water and consumption of bottled water. *Um et al.* [2002] note that households adopt these averting behaviors even when tap water is safe to drink because risk perceptions are often inconsistent with objective indicators of water quality. *Lewis and Pattinasarany* [2009] also suggest that reported perceptions of service quality are only partially associated with the performance of public education in Indonesia. *Andaleeb et al.* [2007] and *Myburgh et al.* [2005] found similar results for public satisfaction from health services in Bangladesh and South Africa, respectively. Accordingly, it can be hypothesized that perceptions of water supply reliability affect the choice of investing in storage devices, and that those perceptions do not necessarily reflect actual system reliability.

[4] This paper aims to identify the determinants of household expenditures on water storage devices using a random sample of 891 geographically stratified households in León, Nicaragua. Particular emphasis is on the effects of perceptions of water supply reliability. These perceptions may vary across water users based on unobserved heterogeneity of individual characteristics and attitudes [*Whitehead*, 2006]. If the same unobserved characteristics also influence household choice of storing water, estimated effects of reliability perceptions on water storage expenditures may suffer from endogeneity bias. This issue has received little attention in previous studies of averting behaviors (see *Dickie and Gerking* [1996] for an exception). In order to control for potential endogeneity of reliability perceptions, this study investigates household expenditures on water storage devices using instrumental variable (IV) Tobit models. Results indicate that nearly 80% of sampled households have at least one water storage device at home on which they expend approximately 0.87% of their income. Perceptions of water supply reliability are found to be the main determinant of household expenditures on storage devices, followed by home ownership and household income.

[5] The rest of the paper is organized as follows. Section 2 describes the study site and survey design. Section 3 presents the theoretical framework used to derive a testable

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hypothesis on the relationship between perceptions of water supply reliability and expenditures on water storage devices. This section also presents the empirical approach consisting of IV Tobit models in which perceptions of water supply reliability are depicted by continuous and ordinal indicators. Section 4 shows the results. Section 5 concludes the paper with a discussion of findings and some policy implications.

2. Study Site and Survey Design

2.1. Current Water Services in León

[6] León is the second largest city of Nicaragua. As of 2005 it had more than 174,000 inhabitants, with 80% of them living in the urban center of the municipality [*Instituto Nacional de Estadisticas y Censos* (*INEC*), 2006a]. More than 94% of León's inhabitants have private access to water, which is above the national average of 80.3% [*INEC*, 2006b]. The city of León obtains its water from the León-Chinandega aquifer. This aquifer is composed of a shallow, unconfined alluvial unit at the top, and a more consolidated volcanic aquifer at the base [*Corriols et al.*, 2009; *Moncrieff et al.*, 2008]. The aquifer is mainly recharged from precipitation. Intensive water pumping for irrigation purposes often induces a sharp decline of the water table particularly during dry seasons [*Calderón Palma and Bentley*, 2007]. As a result, the region is highly prone to water shortages [*Panamerican Health Organization* (*PAHO*) *and Nicaraguan Company of Water and Sanitation* (*ENACAL*), 2004].

[7] The water supply system in León is administered by the Nicaraguan Company of Water and Sanitation (ENACAL). ENACAL is the national public water utility that centrally administrates most of the urban water systems. Concentration of managerial, operational, and financial functions diminishes ENACAL's capacity to maintain water infrastructure and provide reliable water services [*PAHO and ENACAL*, 2004]. Insufficient cost recovery also jeopardizes the maintenance of water infrastructure and the provision of water services. *ENACAL* [2008] reports that more than 50% of water produced does not generate revenues for the utility due to water losses, illegal connections, and lack of water meters. Consequently, ENACAL operates in financial deficit with a significant debt for overdue electricity bills [*ENACAL*, 2008; *Guevara Jerez*, 2007]. While ENACAL is responsible for budgetary decisions, it only plays an advisory role to the Nicaraguan Institute of Water and Sanitation (INAA) for water pricing. INAA is also responsible for regulating water resources and supervising the quality of residential water services provided by ENACAL [*Arze and Martinez-Vazquez*, 2004]. Due to poor system operation and infrastructure maintenance, interruptions of water supply have become more common in recent years [*World Bank*, 2008]. Systematic information on service performance (e.g., service hours and sudden interruptions) is not available. Against this backdrop, it is not surprising to see households investing in water storage devices.

2.2. Survey Design and Sampling Strategy

[8] The survey data used in this study was collected through in-person interviews conducted in May–June 2009. The survey design included a number of semistructured interviews with water management officials, nongovernmental activists, and water users, and went through a number of iterations to incorporate feedback. The survey was pretested with two focus groups of water users. Subsequently, a pilot survey was implemented in the field by trained interviewers with a random sample of 30 households. The survey asked households to report their water uses, practices and expenditures. More specifically, households were asked about their expenditures on acquiring and maintaining water storage devices in the last 12 months. Households were also asked to evaluate the current water system in terms of overall service, supply hours, water quality, and taste using a qualitative five tiered scale ranging from "Very Bad" to "Very Good," and to compare their water supply to that of other households in the city. Finally, the survey collected information about sociodemographic characteristics of respondents and their households.

[9] A stratified random sampling strategy was implemented to select households to be interviewed. Urban León was stratified into eight geographical zones based on a map used by the city of León for assessment and tax purposes in 2002. Then, from each stratum, 15% of parcels were selected. A total of 891 valid responses were obtained for a response rate of nearly 74%. Many of the nonresponses were due to selection of businesses and empty properties as information on property type was not listed in the map.

3. Analytical Framework and Empirical Modeling Approach

[10] The hypotheses tested in this paper are derived from a household-production framework for household behavior regarding water storage. The discussion of this framework is kept to a minimum given that similar theoretical models have been presented elsewhere (see *Janmaat* [2007], *Larson and Gnedenko* [1999], *Pattanayak et al.* [2005] for detailed presentations of the household-production model as applied to household behavior adopted to cope with low quality of water services). Following *Um et al.*'s [2002] perception-averting behavior model, adoption of averting behaviors (e.g., water storage) is considered to result from a two-step process [see also *Adamowicz et al.*, 1997; *Dickie and Gerking*, 1996]. First, households form their perceptions regarding the quality of water services based on their exposure to water supply unreliability. Second, based on their perceptions, households procure water by adopting a number of averting measures. For instance, households collect, pump and purchase water as a response to the perceived unreliability of water supply. Households also treat water at home (e.g., boiling, filtering and chlorinating) to improve water quality for drinking and cooking purposes. These averting measures are beyond the scope of this paper as they have been analyzed elsewhere [e.g., *Abrahams et al.*, 2000; *Jakus et al.*, 2009; *Larson and Gnedenko*, 1999; *Pattanayak et al.*, 2005; *Yoo*, 2005]. The focus here is on household expenditures on water storage devices (e.g., buckets, barrels, sinks, and tanks), an averting measure that has received less attention than others even though it is becoming more common in developing countries (see *Zeráh* [2000] for an exception).

[11] Households are assumed to minimize expenditures on water storage devices in order to procure the amount of

water they need. Water storage expenditures may also affect drinking water quality at the point of consumption depending on the material and shape of storage devices [e.g., *Brick et al.*, 2004; *Quick et al.*, 2002]. Determinants of water storage expenditures include the cost of storage devices, the perceived reliability of water supply, and the optimal level of water to be consumed, which in turn depends on the household income, water fees, and the perceived reliability of water supply. Water storage expenditures are expected to increase with household income given that water storage is deemed a normal good. The response of water storage expenditures to changes in the costs of storage devices is unknown as it depends on price elasticity of the demand for water storage devices. Likewise, the effect of the perceived reliability of water supply on water storage expenditures is ambiguous. There can be a negative substitution effect as households would expend less on water storage devices if water supply is perceived to be reliable. There may also be a reliability effect given that the demand for water may increase (decrease) with better (worse) perceptions of water supply reliability. The reliability effect is positive if water and other goods consumed by the household are normal goods (see *Larson and Gnedenko* [1999] for a detailed derivation of comparative statics). Thus, the total perception effect on water storage expenditures remains to be empirically estimated.

[12] In the empirical approach, household expenditures on acquiring and maintaining water storage devices are assumed to be associated with perceptions of water supply reliability (R^*) and other determinants in a linear form. Observed expenditures on water storage devices (*STOREXP*) are modeled through a Tobit specification in order to account for potential corner solutions (i.e., zero water storage expenditures):

$$STOREXP = \max(0, \beta R^* + Z\delta' + e), \qquad (1)$$

where β is the coefficient that depicts perception effects on household expenditures on storage devices. Z is a vector of household characteristics that may impact household expenditures on storage devices (i.e., home ownership, as well as household income and size). That impact is estimated through the conformable vector of coefficients δ. The error term e, which includes unobserved respondent and household characteristics, is assumed to be normally distributed (i.e., $e \sim N[0, \sigma^2]$).

[13] Table 1 shows definitions and descriptive statistics of the variables used to estimate Tobit models of water storage expenditures. Perceptions of water supply reliability (R^*) are represented by a number of indicators based on qualitative ratings of overall service, daily hours with water supply, water quality, and water taste using a five tiered scale ranging from "Very Bad" to "Very Good." *PERCINDEX* is a standardized index of perceptions of water supply reliability estimated through factor analysis of the qualitative ratings (see details below in section 4.1). This index is used to estimate the storage expenditure model given that households may expend on water storage devices based on their perceptions of both quantity and quality aspects of water. It can also be argued that water storage expenditures are more responsive to perceptions of water availability than to water quality perceptions. To address this possibility, the variable *HOURSCORE* is also used to estimate the expenditure model. *HOURSCORE* is an ordinal indicator depicting respondents' ratings of daily hours with water supply. The total effect of perception variables is to be empirically estimated as the theoretical framework shows that it consists of opposing substitution and reliability effects. In addition, the variable *INCOME* is included to estimate its effect on household expenditures on storage devices, which is expected to be positive as water storage is assumed to be a normal good (i.e., $\delta_{INCOME} > 0$). The vector of respondent and household characteristics (Z) also includes the variables *OWN* and *HHSIZE*. Compared to home renters, home owners may invest more in water storage devices to increase the value of their property (i.e., $\delta_{OWN} > 0$). Household size is also expected to have a positive effect on storage expenditure given that the demand for water increases with the number of household members (i.e., $\delta_{HHSIZE} > 0$).

[14] *Deichmann and Lall* [2007] and *Vásquez and Trudeau* [2011] argue that perceptions of the reliability of water services are related to service performance and personal characteristics that vary across individuals [see also

Table 1. Variables Definition and Descriptive Statistics[a]

Variable	Definition	Mean	SD
STOREXP	Household expenditures on maintenance and acquisition of storage devices (of those households who reported to have storage devices) in the 12 months previous to survey implementation	371.51	1097.14
PERCINDEX	Standardized (latent) index on perceptions of the quality of water services	0	1
HOURSCORE	Subjective perception of the daily hours with water supply on a 5 point scale (1 = very bad, 2 = bad, 3 = average, 4 = good, 5 = very good)	3.33	1.00
INCOME	Household's monthly income grouping, in Nicaraguan Cordobas (0 = no income, 1 = less than 1000, 2 = 1001 to 2000, 3 = 2001 to 3000, 4 = 3001 to 4000, 5 = 4001 to 5000, 6 = 5001 to 6000, 7 = 6001 to 7000, 8 = 7001 to 8000, 9 = 9001 to 10,000, 10 = more than 10,000)	4.03	2.99
EDUC	Education of the respondent (no. of schooling years)	10.02	4.75
OWN	If the respondent household is owner of the house (1 = Yes, 0 = Otherwise)	0.87	0.34
HHSIZE	The number of individuals living in the respondent household	5.05	3.05
HOURS	Number of daily hours with water supply reported by respondents	19.63	6.30
WORSE	If the respondent reports to receive water services less hours per day than her peers (1 = Yes, 0 = Otherwise)	0.19	0.39
AGE	Age of the respondent (in years)	42.83	16.94
FEMALE	Gender of respondent (1 = female, 0 = male)	0.66	0.47

[a]Household income and expenses on maintenance and acquisition of water storage devices are expressed in Nicaraguan currency, Cordoba (1 US$ is equivalent to 20.566 Nicaraguan Cordobas as of 1 June 2009).

Lewis and Pattinasarany, 2009; *Whitehead*, 2006]. If unobserved characteristics included in the error term (e) also influence perceptions of water supply reliability (i.e., the perceived reliability of water supply R^* is endogenous), estimates of the β coefficient will be biased. To control for this endogeneity issue, perceptions of water supply reliability are modeled as follows:

$$R^* = \alpha HOURS + \theta\phi' + u, \tag{2}$$

where *HOURS* represents daily hours with water supply as a measure of service performance. The coefficient α depicts the association between perceptions and service performance. θ is a vector of covariates including a relative assessment of hours with water supply compared to peers (i.e., *WORSE*), as well as respondent and household characteristics (i.e., *EDUC*, *AGE*, *FEMALE*, *INCOME*, *OWN* and *HHSIZE*). ϕ is a conformable vector of coefficients to be estimated and u is the error term. IV Tobit models consisting of equations (1) and (2) are simultaneously estimated using a maximum likelihood method that allows error terms e and u to be correlated (i.e., $\rho = \text{corr}[e, u]$). Statistically significant correlation estimates would imply that R^* is endogenous and that the simultaneous estimation strategy used here is suitable to correct the endogeneity bias of the β coefficient (see *Whitehead* [2006] for a discussion of endogenous perceptions of water quality in WTP models). To complement the analysis of storage expenditures, IV Probit models are also estimated to investigate the household decision on using small and large storage devices.

[15] Note that the theoretical framework and empirical models are consistent in that households decide on water storage through a two-step process in which objective indicators of service performance may affect storage expenditures only indirectly through perceptions of water supply reliability. This assumption is particularly valid when water supply interruptions are unpredictable due to the lack of systematic service performance information and system unreliability [see *Um et al.*, 2002], as is the case in Nicaragua. Hence, the performance indicator *HOURS* is used as an identifying variable (i.e., included in equation (2) and excluded from equation (1)). Respondents who report a greater number of daily hours with water supply are expected to have better perceptions of water supply reliability (i.e., $\alpha_{HOURS} > 0$). In addition, following *Deichmann and Lall* [2007], the vector θ includes the binary indicator *WORSE* to depict differentials in perceptions between those who report receiving worse services than their peers and those who do not. Respondents who report receiving worse services than their peers are expected to have lower reliability perceptions than those who report having similar or better services (i.e., $\phi_{WORSE} < 0$). Following *Whitehead* [2006], who argues that personal characteristics are often unrelated to payments (or willingness to pay) for water improvements but strongly associated with water quality perceptions [see also *Deichmann and Lall*, 2007], *EDUC*, *AGE*, and *FEMALE* are used as identifying variables. These respondents' characteristics are assumed to be unrelated to storage expenditures as water storage is a household decision rather than an individual one.

4. Survey and Estimation Results

[16] The average respondent is approximately 43 years old, with about 10 years of schooling (see Table 1). About two thirds of the sample are females. Nearly 87% of sampled households own their homes, and the average household consists of about five members. On average, the monthly household income is 3572.15 Cordobas (or 173.69 US dollars) and the monthly water bill is 249.65 Cordobas (12.13 US dollars). Approximately 80% of sampled households store water at home spending an average of 371.51 Cordobas per year (about 18 US dollars) on storage devices. If households who do not store water at home are included, the expected annual expenditure on water storage devices is 300.51 Cordobas (14.61 US dollars).

4.1. Perceptions and Averting Behavior of Sampled Households

[17] Table 2 shows how respondents perceive overall water services, the number of daily hours with water supply, and the quality and taste of tap water. Most water users rate these service characteristics as "Good", with the exception of overall service that is perceived as "Regular" by more than 41% of respondents. Many respondents have negative perceptions of overall services and daily hours with water supply (more than 24% and 19%, respectively). In contrast, a low percentage of respondents give a negative rating to both quality and taste of water. This suggests that respondents are primarily concerned about the overall service and daily hours with water supply. These ratings differ from those indicated by previous studies which report a high concentration of the highest level of citizen satisfaction even though there exists evidence of low service performance [e.g., *Andaleeb et al.*, 2007; *Deichmann and Lall*, 2007; *Lewis and Pattinasarany*, 2009; *Myburgh et al.*, 2005].

[18] Factor analysis of the ratings of service characteristics was conducted to uncover the latent household perception of water supply reliability. The four ratings are found to be correlated to a single, unidimensional factor, namely, perception of water supply reliability. Factor loadings show a high association between ratings and perception of water supply reliability (see Table 2). The rating of daily hours with water supply has the highest correlation with perceptions of

Table 2. Perceptions of Water Service Quality[a]

	Scores					Factor Analysis	
	Very Bad	Bad	Regular	Good	Very Good	Factor Loading	KMO
Overall water service	6.62%	17.85%	41.64%	28.96%	4.94%	0.848	0.647
Daily hours with water supply	5.27%	14.03%	32.10%	39.51%	9.09%	0.857	0.663
Quality of tap water	1.01%	6.40%	31.09%	55.56%	5.95%	0.627	0.671
Taste of tap water	0.34%	4.60%	23.12%	64.65%	7.30%	0.471	0.626

[a]Eigen value for first factor = 2.069. Overall KMO (Kaiser–Meyer–Olkin) statistic = 0.653.

supply reliability, followed by the rating of overall water services. The Kaiser-Meyer-Olkin (KMO) statistics are above the critical level of 0.6 [see *Kaiser and Rice*, 1974] implying that correlations between ratings and reliability perception (i.e., factor loadings) are statistically significant. Therefore, all ratings are used to estimate a standardized index of perceptions of water supply reliability (i.e., *PERCINDEX*) based on the regression scoring method.

[19] Table 3 shows some behaviors that households adopt to cope with unreliable water supply, and how those behaviors vary across perception levels of daily hours with water supply. On average, households report a water supply of more than 19 h per day. There is, however, significant variation in daily hours with water supply across respondent's perceptions. Households perceiving daily hours with water supply as "Very Good" receive tap water almost continuously. However, households with "Very Bad" perceptions receive water less than 10 h per day. Despite the reported number of hours with water supply, almost 80% of respondents report to have at least one water storage device at home on which they expend an average of 371.51 Cordobas ($18.06) per year. Such expenditures are equal to 0.87% of the average household income. *Pattanayak et al.* [2005] estimate that households in Kathmandu, Nepal expend about 1% of their income on averting measures including water storing. Again, respondents with negative perceptions of hours with water supply are more likely to use water storage devices and expend more on them. All respondents who rate daily hours with water supply as "Very Bad" have at least one water storage device at home and report an annual household expenditure of more than 260% of pooled average expenditures. In contrast, less than 70% of households with "Good" and "Very Good" perceptions use water storage devices, and expend less than 50% of pooled average expenditures.

[20] Overall, sinks are the most popular water storage device, although households with negative perceptions of daily hours of water supply tend to prefer barrels. Sinks are multipurpose devices, with households also using them to wash dishes and clothes. Buckets and barrels are also widely used to store water, followed by plastic bottles. These devices require little effort to maintain and, as shown in Table 4, are relatively inexpensive in León. More expensive devices such as plastic tanks are used only by a minority of respondents even though they can store more water than inexpensive devices. Household preferences for inexpensive devices with low storing capacity suggest income constraints.

4.2. Determinants of Household Expenditures on Water Storage Devices

[21] Table 5 shows the marginal effects derived from four Tobit models used to investigate the impact of perceptions of water supply reliability on water storage expenditures. In Models 1 and 2, it is assumed that reliability perceptions are exogenous. Models 3A and 4A are IV Tobit models (consisting of equations (1) and (2)) that control for potential endogeneity of reliability perceptions. Perceptions of water supply reliability are measured using two types of indicators. First, the standardized index *PERCINDEX* is used to estimate Models 1 and 3A. Second, reliability perceptions are depicted by the five tiered scale (ranging from "Very Bad" to "Very Good") that respondents used to rate daily hours with water supply. This ordinal indicator of reliability perceptions (i.e., *HOURSCORE*) is used to estimate Models 2 and 4A. Given the ordinal nature of *HOURSCORE*, model 4A is estimated as a simultaneous equations system composed of a Tobit model of water storage expenditures and an ordered probit model of reliability perceptions. *Winship and Mare* [1984] argue that ordinal variables can be used as predictors if they are linearly related to the unobserved continuous perception measure and if they are simultaneously modeled as an instrumental variable. The factor loading corresponding to ratings of daily hours with water supply in Table 2 indicates that the ordinal indicator

Table 3. Averting Behavior of Sampled Households[a]

Description	Pooled Sample	Very Bad	Bad	Regular	Good	Very Good
Number of daily hours with water supply	19.63 (6.30)	9.89 (4.73)	12.96 (5.84)	18.81 (6.25)	23.02 (2.93)	23.77 (1.89)
Annual household expenses on maintenance and acquisition of water storage devices (of those households who reported to have storage devices)	371.51 (1097.14)	973.69 (2176.82)	341.90 (740.07)	377.89 (1369.21)	160.22 (544.33)	103.44 (319.58)
Percentage of households with at least one water storage device at home	79.4%	100%	96.8%	84.1%	69.9%	64.6%
Percentage of households with sinks to store water	42.4%	48.9%	47.2%	45.9%	38.0%	38.0%
Percentage of households with buckets to store water	30.5%	48.9%	44.8%	33.9%	24.3%	12.7%
Percentage of households with barrels to store water	29.6%	59.6%	52.8%	31.8%	18.9%	15.2%
Percentage of households with plastic bottles to store water	24.4%	46.8%	32.8%	26.1%	18.6%	17.7%
Percentage of households with plastic tanks to store water	15.1%	34.0%	25.6%	17.3%	8.9%	7.6%
Percentage of households with metal tanks to store water	2.3%	6.4%	4.8%	2.1%	0.8%	2.5%
Percentage of households with other water storage devices at home	8.0%	6.4%	12.8%	12.7%	4.0%	2.5%

[a]Numbers in parentheses are corresponding standard deviations. Household expenses on maintenance and acquisition of water storage devices are expressed in Nicaraguan currency, Cordoba (1 US$ is equivalent to 20.566 Nicaraguan Cordobas as of 1 June 2009).

Table 4. Capacity and Costs of Water Storage Devices[a]

	Storage Capacity (in Gallons)	Cost
Plastic Bottle	≤1	NA
Bucket	5.33	160
Sink	8	1200
Barrel	52	400
Metal Tank	52	400
Plastic Tank	106.67	2800

[a]Cost of water storage devices are expressed in Nicaraguan currency, Cordoba (1 US$ is equivalent to 20.566 Nicaraguan Cordobas as of 1 June 2009).

HOURSCORE is linearly associated with latent perceptions of water supply reliability.

[22] Results show a considerable degree of robustness across all models with the exception of the magnitude of estimated coefficients on perception variables (see Table 5). Models 1 and 2, which do not control for perceptions endogeneity, underestimate the effect that reliability perceptions have on water storage expenditures by more than 75 Cordobas due to endogeneity bias. Correlation estimates (ρ) presented in Table 5 are statistically significant (also see Table 6), which suggests that perceptions of water supply reliability are an endogenous predictor of household expenditures on water storage devices. In addition, the Amemiya-Lee-Newey test of overidentifying restrictions suggests that instruments used to model reliability perceptions are valid ($\chi^2 = 2.34, p = 0.5054$). This evidence suggests that Models 3A and 4A are more appropriate to investigate the effect of perceptions on water storage expenditures than Models 1 and 2.

[23] The estimated coefficient on *PERCINDEX* is negative and statistically significant (at 1% level), implying that households with lower perceptions of water supply reliability tend to expend more on water storage devices than households with better reliability perceptions (see model 3A in Table 5). In model 4A, the estimated coefficient on *HOURSCORE* also suggests that household expenditures on water storage devices increase with lower perceptions of water supply reliability. These results are consistent with previous studies that indicate that households with positive perceptions of water quality are less likely to adopt averting behaviors such as bottled water consumption and in-home water treatment [e.g., *Abdalla et al.*, 1992; *Jakus et al.*, 2009; *Yoo*, 2003].

[24] Table 5 also shows that water storage expenditures increase with household income in accord with the hypothesis that water storage is a normal good. This suggests that poor households are more vulnerable to unreliable water supplies than households with higher income. In addition, home owners tend to expend more on storage devices than home renters. Compared to home owners who are less likely to move, home renters may purchase less and smaller water storage devices as these are easier to transport in case they move. Also, home owners may invest more in water storage devices expecting to recover such investments if they decide to sell their homes. Household size seems to have no effect on water storage expenditures.

[25] Table 6 shows marginal effects from two IV Probit models estimated to further investigate household preferences for small (i.e., plastic bottles, buckets and sinks) and large (i.e., barrels, metal tanks, and plastic tanks) storage devices. These models also control for potential endogeneity of reliability perceptions (i.e., *PERCINDEX*) based on the same instruments used in IV Tobit models of water storage expenditures. Results suggest that perceptions of water supply reliability are the main determinant of household choices on storage devices regardless their storage capacity. Interestingly, household income is significant only for large devices. Similarly, using regression analysis, *Zérah* [2000] found that income is directly related to water storage capacity in Delhi, India. *Larson and Gnedenko* [1999] argue that income is not a binding constraint for low-cost averting measures and therefore the income effect could be small or statistically insignificant. This might be the case of small storage devices which are less expensive than large storage devices in León (see Table 4). Moreover, given that devices with more storage capacity are more expensive, household expenditures on storage devices may be expected to increase with income as indicated by water storage expenditure models presented in Table 5.

4.3. Perception Models

[26] Table 7 shows estimation results on the structure of reliability perceptions. Models 3B and 4B were simultaneously estimated with Models 3A and 4A shown in Table 5, respectively, in order to control for endogeneity of reliability perceptions. In model 3B, the estimated coefficients measure, in standard deviations, the effect of corresponding covariates on perceptions of water supply reliability. In model 4B, reliability perceptions are estimated using an

Table 5. Tobit Models of Household Expenses on Water Storage Devices (Marginal Effects)[a]

Dep. Var. = STOREXP	Model 1	Model 2	Model 3A	Model 4A
PERCINDEX	−185.555 (39.257)[b]	–	−275.085 (61.679)[b]	–
HOURSCORE	–	−184.263 (37.165)[b]	–	−262.061 (58.849)[b]
INCOME	24.480 (8.074)[b]	24.545 (8.249)[b]	24.466 (8.118)[b]	25.224 (8.285)[b]
OWN	108.897 (46.033)[c]	111.628 (47.109)[c]	107.361 (47.588)[c]	113.812 (48.793)[c]
HHSIZE	8.558 (8.175)	9.025 (7.863)	8.899 (8.785)	9.700 (8.258)
Corrected for Endogeneity	No	No	Yes	Yes
ρ	–	–	0.235 (0.071)[b]	0.238 (0.072)[b]
Observations	848	848	846	846
Censored Obs	578	578	577	577
AIC	5329.45	5330.81	7263.73	7193.10
BIC	5357.91	5359.27	7344.32	7283.17

[a]Numbers in parentheses are corresponding robust standard errors.
[b]Significant at 1% level.
[c]Significant at 5% level. Numbers in parentheses are corresponding robust standard errors.

Table 6. IV Probit Models of Water Storage Devices (Marginal Effects)[a]

Dep. Var.	*SMALL*	*LARGE*
PERCINDEX	−0.169 (0.026)[b]	−0.285 (0.024)[b]
INCOME	0.002 (0.006)	0.015 (0.006)[b]
OWN	0.022 (0.050)	0.080 (0.049)
HHSIZE	0.013 (0.006)[c]	0.001 (0.007)
ρ	0.281 (0.069)[b]	0.386 (0.060)[b]
P(Dep. Var. = 1)	0.637	0.405
Observations	846	846
AIC	3039.65	2966.62
BIC	3115.49	3042.47

[a]Numbers in parentheses are corresponding robust standard errors.
[b]Significant at 1% level.
[c]Significant at 5% level. Numbers in parentheses are corresponding robust standard errors.

ordered probit model given that *HOURSCORE* is an ordinal indicator of perceptions (corresponding marginal effects are presented in Appendix A). Findings indicate that perceptions of supply reliability are consistent with service performance as measured by the number of hours with tap water per day. Existing studies on satisfaction with public services also indicate that user perceptions are partially related to service performance measures [*Andaleeb et al.*, 2007; *Lewis and Pattinasarany*, 2009]. However, estimated coefficients on *WORSE* point to assessment of service hours relative to peers as the main determinant of reliability perceptions. IV Probit models yield similar results indicating that both daily hours with water supply and relative assessment of services hours impact reliability perceptions (these results are not presented here but are available upon request). *Deichmann and Lall* [2007] present similar evidence on the association between citizen feedback and relative assessment of water services. Findings also indicate that other respondent and household characteristics do not affect perceptions of water supply reliability. In contrast, *Lee et al.* [2009] and *Lewis and Pattinasarany* [2009] found that some individual and household characteristics (e.g., age, education, and income) are related to perceived quality of national health insurance in South Korea and public education in Indonesia, respectively. Overall, León's inhabitants seem to base their reliability perceptions on water service characteristics.

Table 7. Perception Models

	Model 3B, *PERCINDEX*[a]	Model 4B, *HOURSCORE*[b]
HOURS	0.083 (0.005)[c]	0.125 (0.008)[c]
WORSE	−0.527 (0.089)[c]	−0.700 (0.117)[c]
EDUC	0.0001 (0.007)	0.007 (0.010)
AGE	0.001 (0.002)	0.002 (0.002)
FEMALE	0.003 (0.056)	0.013 (0.083)
INCOME	−0.004 (0.011)	0.0002 (0.014)
OWN	0.042 (0.075)	0.120 (0.110)
HHSIZE	−0.0002 (0.009)	0.005 (0.012)
CONSTANT	−1.603 (0.181)[c]	–

[a]Regression model for standardized perception index.
[b]Ordered probit model (see marginal effects in Appendix A). Estimated threshold parameters are 0.238 (0.251), 1.398 (0.257), 2.804 (0.273), and 4.374 (0.284).
[c]Significant at 1% level. Numbers in parentheses are corresponding robust standard errors.

5. Conclusions

[27] This paper investigates water storage expenditures at the household level in a developing country context, with particular emphasis on perception effects. Survey results indicate that a majority of households in León, Nicaragua have at least one device to store water on which they expend 0.87% of their annual income. This evidence indicates a latent demand for more reliable water supply in León, Nicaragua. As a point of comparison, *Vásquez et al.* [2009] estimate through contingent valuation methods that households in Parral, Mexico are willing to pay at least 1% of their income for a perfectly reliable water supply system. Results suggest that perceptions of water supply reliability are the main determinant of household expenditures on water storage devices. Income and home ownership are also found to positively impact those expenditures. Findings also indicate that perceptions of water supply reliability are associated with service performance (as measured by daily hours with water supply) and assessment of service hours relative to peers.

[28] Perceptions of system reliability can be improved by increasing the number of daily hours of water provision. As a result, household would reduce their expenditures on water storage devices. If water is provided one more hour per day, the expected annual expenditure on water devices currently estimated at 301 Cordobas (14.61 US dollars) would decrease to 277 Cordobas (13.50 US dollars). That decrease in storage expenditures is approximately 9.6% of the average water bill. A reduction in storage expenditures is also expected from providing equal services to water users across the service area given that, by affecting user perceptions of water supply reliability, unequal provision of water services exacerbates household expenditures on water storage devices. Households would reduce their annual water storage expenditures to 273 Cordobas (13.29 US dollars) if equal provision is achieved. Providing water with same frequency across households may not require costly investments [*Baisa et al.*, 2010].

[29] Current household expenditures on water storage devices can be considered a lower bound of households' willingness to pay (WTP) for reliable water supply. Thus, reductions of water storage expenditures can be used as welfare estimates for cost-benefit analysis of improvements of water supply reliability [see *Pattanayak et al.*, 2005]. Moreover, estimated structural parameters of water storage expenditures will support out-of-sample projections of (a lower bound of) WTP for reliable water systems. As noted by earlier studies [*Griffin and Mjelde*, 2000; *Howe et al.*, 1994], improved understanding of household preferences can help identify the preferred level of services and provide information for pricing, affordability and equity policies aimed to improve water supply reliability. Hence, results from this study prove to be useful for effective water policy design.

Appendix A: Marginal Effects on User Perceptions Based on Ordered Probit Model

[30] Table A1 presents the marginal effects of *HOURS* and *WORSE* on the probability of rating the daily hours with water supply as "Very Bad" to "Very Good" based

Table A1. Marginal Effects of Selected Variables

	Very Bad	Bad	Regular	Good	Very Good
HOURS	−0.003 (0.001)[a]	−0.020 (0.002)[a]	−0.026 (0.003)[a]	0.038 (0.003)[a]	0.011 (0.001)[a]
WORSE	0.028 (0.010)[a]	0.139 (0.028)[a]	0.087 (0.013)[a]	−0.211 (0.033)[a]	−0.043 (0.007)[a]
Predicted Probability	0.008	0.100	0.460	0.391	0.041

[a]Implies significance at 1%; numbers in parentheses are corresponding robust standard errors. The marginal effects of excluded covariates are statistically insignificant.

on the (ordinal probit) Model 4B (see Table 7). As expected, a marginal increase in *HOURS* decreases the probability of negative ratings (i.e., "Very Bad" to "Regular") and increases the probability of rating the system as "Good" and "Very Good". For instance, estimated effects indicate that the probability of rating the daily hours with water supply as "Very Bad" decreases by 0.3 percentage points with a marginal increase in *HOURS*. In addition, a marginal increase in *WORSE* increases the probability of negative ratings and decrease the probability of positive ratings.

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