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Abstract

Objectives: This article examines the effect of water system unreliability on diarrhea incidence among children aged 0-5 in Guatemala.

Methods: We use secondary data from a nationally-representative sample of 7,579 children to estimate the effects of uninterrupted and interrupted water services on diarrhea incidence. The national scope of this study imposes some methodological challenges due to unobserved geographical heterogeneity. To address this issue, we estimate mixed-effects logit models that control for unobserved heterogeneity by estimating random effects of selected covariates that can vary across geographical areas (i.e. water system reliability).

Results: Compared to children without access to piped water, children with uninterrupted water services have a lower probability of diarrhea incidence by approximately 33 percentage points. Conversely, there is no differential effect between children without access and those with at least one day of service interruptions in the previous month. Results also confirm negative effects of age, female gender, Spanish language, and garbage disposal on diarrhea incidence.

Conclusions: Public health benefits of piped water are realized through uninterrupted provision of service not merely access. Policy implications are discussed.

Keywords: Guatemala; diarrheal incidence; morbidity; tap water; service interruptions

Introduction

Diarrheal diseases remain a leading cause of child mortality worldwide, accounting for an estimated 9% of deaths among children aged 0-5 years (WHO 2015a). In Guatemala, diarrheal diseases account for an estimated 7% of child deaths and 13% of post neonatal deaths (aged 1-5) (UNICEF 2015). Moreover, the morbidity burden is high. During the Guatemalan Demographic and Health Survey conducted in 2008-2009, 23% of children aged 0-5 had experienced an episode of diarrhea in the two weeks prior to the survey (WHO 2015b). Repeated diarrheal infections contribute to the high rate of stunting among Guatemalan children, at 46.5% of those aged 0-5 (WHO 2015c; Checkley et al. 2008).

Approximately 88% of diarrhea-associated deaths are attributable to unsafe water, inadequate sanitation, and insufficient hygiene (Prüss-Üstün et al. 2008). With the potential to reduce mortality and morbidity, the Millennium Development Goals of 1990 included halving the proportion of people without access to safe drinking water and basic sanitation by 2015, and currently the Sustainable Development Goals call for universal provision worldwide by 2030. Globally, access to improved drinking water increased from 76% in 1990 to 91% in 2015.[1] Yet, over this period, several studies have found limited health improvements due to that increase (Wolf et al. 2014; Waddington et al. 2009; DeWilde et al. 2008). In Guatemala, for instance, a recent examination of piped water access found only modest reductions in diarrheal incidence among children (Vásquez and Aksan 2015).

As of 2014, 76.3% of Guatemalans had access to improved water services in the form of home connections to a water system and, to a lower extent, access to a public standpipe, with a

[1] The WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation defines improved access as having a piped household water connection located inside the user's dwelling or plot, or access to public taps/standpipes, tube wells or boreholes, protected dug wells or springs, and rainwater collection.

large disparity in access between urban (89%) and rural (64%) households (SEGEPLAN 2015). As in many low- and middle-income settings around the world (Brown et al. 2013; Thompson et al. 2000; Schouten and Moriarty 2003), water services in Guatemala are frequently interrupted (Vásquez 2013, 2016b). To cope with these interruptions, households store water at home and collect water from alternative sources which may be of poor quality. Using survey data from a small town in western Guatemala, Vásquez (2016a) shows that household choice of storing water in second-hand barrels is directly related to water service interruptions. Water storage practices can breed disease if storage devices are not covered, sanitized appropriately, or are larger than necessary so that water is stored too long. Contamination due to water storage practices has been linked repeatedly to diarrheal disease (Gunther and Schipper 2013; Wolf et al. 2014) and growth of disease vectors such as the mosquito carrier of dengue (Majuru et al. 2016; Thompson et al. 2000). Households may also respond to supply interruptions by reducing water usage for personal and home hygiene such as bathing, handwashing, laundry, dishwashing, and washing floors (Evans et al. 2013; Majuru et al 2016; Smiley 2016; Wolf et al. 2014). Hygiene interventions, handwashing in particular, reduce the incidence of diarrhea (Aiello et al. 2008; Ejemot-Nwadiaro et al. 2015; Thompson et al. 2000; Waddington et al. 2009). Moreover, water supply unreliability can adversely affect water quality by introducing contaminants during periods of low pressure or supply interruption (Majuru et al. 2016; Wolf et al. 2014; Matsinhe et al. 2014).

Few studies have examined the link between water system unreliability and health outcomes. A study of two Ugandan water systems found that even a few days of interruption in water service, by forcing the populations to consume untreated surface water, completely negated many of the health benefits associated with having access to a treated water source, as measured by risk of infection by several common water-borne pathogens. Both adult and child morbidity were affected (Hunter et al. 2009). A study of three remote communities in rural South Africa yielded similar findings. While diarrheal incidence declined for two communities that implemented a water system relative to the third control, the decline was greater in the community where the system was more reliable (Majuru et al. 2011). Similarly, Jeandron et al. (2015) found that even a single day of interrupted water supply increased cholera incidence in Uvira, Democratic Republic of the Congo, especially in neighborhoods that rely more heavily on piped water. Frequent water service interruptions in Guatemala (Vásquez 2013, 2016b) could explain why prior studies have found a minimal impact of piped water access on diarrheal incidence among children there (e.g. Vásquez and Aksan 2015).

We investigate the effects of water service unreliability on diarrheal incidence among a nationally-representative sample of 7,579 children aged 0-5 in Guatemala. Although existing community level studies have demonstrated that water service interruptions negate the potential of piped water access to reduce morbidity in other developing countries (Hunter et al. 2009; Jeandron et al. 2015; Majuru et al. 2011), to the best of our knowledge we are the first to conduct this analysis using national level data. This broader scope imposes some methodological challenges due to geographical heterogeneity of unobserved characteristics (e.g. piped water quality and access to alternative fresh water sources) that could bias the results. We estimate a number of mixed-effects logit models to measure the effect of water service unreliability on diarrheal incidence among children while controlling for unobserved geographical heterogeneity in our data. Our findings indicate that diarrheal incidence is 32.9% lower among children living in households with reliable access versus those without piped water in the home, while diarrheal incidence is similar between children in households without piped water and those with unreliable service.

Methods

This study uses secondary data from the 2014 Living Standards Measurement Survey, referred to as Encuesta Nacional de Condiciones de Vida 2014 (ENCOVI) in Guatemala. It is the most recent ENCOVI survey administered by the Guatemalan Institute of Statistics, designed to collect data on living standards and determinants of poverty. ENCOVI follows a two-stage sampling design to be representative at the national and departmental levels. The country is initially divided into rural and urban areas in 22 departments for a total of 44 areas. The first stage consists of a stratified sampling procedure implemented at the area level. Using indicators on unsatisfied basic needs, primary sampling units (PSUs) are classified into five strata (very low, low, medium, medium high, and high). A total of 1,037 PSUs are randomly selected in the first stage. In the second stage, two secondary sampling units (SSUs) consisting of clusters of households are systematically selected. A total of 11,536 households completed the questionnaire.

Sampled households report whether every child aged 0-5 in the residence suffered a diarrheal episode in the month prior to survey implementation (for a total of 7,579 children). Given the binary nature of this indicator, logit models may seem appropriate to investigate factors related to diarrhea incidence. However, considerable geographical heterogeneity may exist in service characteristics (e.g. quality and reliability of tap water) and related health policies and programs. For this reason, we estimate mixed-effects logit models that are suitable to investigate factors associated with diarrhea incidence in the presence of regional heterogeneity.

Ferrer et al. (2008), Komarulzaman et al. (2016), and Vásquez and Aksan (2015) present recent examples of estimating mixed-effects models to identify factors determining the incidence of diarrhea, though its application is not limited to this outcome. For example, Adams et al. (2009) use multi-level mixed-effects models to investigate neighborhood-level variation in the socioeconomic determinants of chronic health outcomes, including obesity, diabetes, and physical and mental health reports.

Given the sampling strategy applied in ENCOVI, we implement a mixed-effects logit estimation with two levels. At the first level, the indicator DIARRHEA_{ij} takes the value of one if child *i* in sampling area *j* experienced diarrhea in the month prior to the survey implementation. Otherwise DIARRHEA_{ij} takes the value of zero. In the second level, we account for regional heterogeneity by allowing some coefficients to vary across PSUs. The two-level logit models are specified as follows:

$$\text{logit}\,(p_{ij}) = X_{ij}\beta + Z_{ij}u_j + e_{ij} \qquad (1)$$

where $p_{ij} = \Pr(\text{DIARRHEA}_{ij} = 1)$, X is the vector of factors associated with diarrhea incidence, Z is a subset of factors assumed to have heterogeneous effects across sampling areas, and e is the error term that follows a logistic distribution. β is the vector of relevant fixed effect coefficients to be estimated; and u_j is a set of random effects that depict regional heterogeneity across sampling areas. The so-called random-intercept logit model is obtained when vector Z is reduced to a vector of ones. In this model, the effects of covariates on diarrhea incidence are assumed to be fixed, but the intercept is allowed to vary across geographical areas to account for heterogeneity. As an extension of this model, a subset of variables can be included in vector Z to estimate a random-coefficient logit model in which the estimated effects of those variables are allowed to randomly vary across geographical areas. We explore the possibility that water service reliability can have mixed (fixed and random) effects on diarrhea incidence by including a reliability indicator in vector *Z*.

Table 1 presents the definitions of factors included in vector *X*. These factors include two binary indicators of the reliability of water service for houses that are connected to a water system: RELIABLE indicates that the household had zero service interruptions, and UNRELIABLE indicates that the household experienced service interruptions in at least one day of the month prior to survey implementation. Children in households without water services are used as base for comparison. We expect that reliable water services help reduce the incidence of diarrhea among children given that improved access to water facilitates hygiene practices at home (Cairncross and Valdmanis 2006). On the other hand, water service interruptions may induce households to adopt unsafe behaviors such as reducing hygiene practices and inappropriately storing water at home (Evans et al. 2013; Majuru et al. 2016; Vásquez 2016a; Wolf et al. 2014). Therefore, we hypothesize that unreliable services are ineffective in reducing diarrhea incidence.

Additional service characteristics include whether the house is connected to a sewer system and if it uses a garbage disposal service. Each measure may promote health by decreasing contamination via waste removal. Vásquez and Aksan (2015) find a negative association between sewer connections and diarrhea incidence in Guatemala, and Rego et al. (2005) observes a higher probability of diarrhea associated with environmental exposure to garbage, which has high contamination of feces in Salvador, Brazil. Vector *X* also accounts for the existence of a devoted room for the kitchen and for materials used in construction of the walls, roof and floor of the home. It is expected that improved housing conditions facilitate hygiene practices at home and in turn reduce diarrhea incidence. We control for home treatment of drinking water via filtration, boiling, chlorination or purchase of bottled water, which have been shown to reduce diarrhea incidence (Reller et al., 2003); although as previously discussed, the home treatment methods' beneficial effects could be mediated by ineffective storage practices (Vásquez 2016a), not available in our data. Finally, we include individual characteristics (i.e. age and gender), as well as household attributes (i.e. language spoken in the home, average number of people per room in residence and whether the home is located in a rural area) to account for heterogeneity within and across households. The models presented in the next section were estimated using the *logit* and *meqrlogit* commands in STATA v.14.

Results

Table 1 summarizes the individual and household characteristics of the sample. At the national level, 19% of the sampled children had at least one incident of diarrhea in the last month. Approximately 43.9% live in a home that reports RELIABLE service, 26.4% live in a home with UNRELIABLE service, and 29.7% of children do not have access to piped water at home. Comparing children with and without diarrhea, as expected, children experiencing diarrhea live in households with lower prevalence of water access, reliable water access, and sewer and garbage service, and have worse physical housing characteristics. Water treatment patterns are less clear, with similar prevalence of chlorinating water among the two groups and less filtered and bottled water but more boiled water among household with diarrhea incidence. Interestingly, prevalence of unreliable water access is similar across the two groups. To determine which of these factors drive the difference in diarrhea incidence across children, we turn to regression analysis.

Figure 1a shows considerable variation in diarrhea incidence across states. The highest incidence of diarrhea is observed in the northwestern states of Huehuetenango, Quiché, Alta Verapaz, and Baja Verapaz, and southwestern Retalhuleu (22.9 – 40.4%). Figure 1b demonstrates considerable geographic variation in access to water (RELIABLE+UNRELIABLE), but the relationship with diarrhea incidence is not clear. For instance, Quiché and Baja Verapaz fall within the third quartile of access to piped water (68.7-78.8%), yet they are among the states with highest incidence of diarrhea. Similarly, the south-central state of Guatemala has one of the highest piped water coverage rates, but it remains among the states with moderately high diarrhea incidence (17.3-22.9%). Figure 2 presents a breakdown of the fraction of the population in each state that reports RELIABLE, UNRELIABLE, or no service for the previous month in rank order of low to high diarrhea incidence. These figures suggest a negative link between RELIABLE and diarrhea, although there are some notable exceptions. For example, whereas Sololá has the second highest RELIABLE rate and highest access rate (RELIABLE+UNRELIABLE, 94%), it has the 10th highest rate of diarrhea. Figures 1 and 2 demonstrate considerable geographic heterogeneity in water service provision. Therefore, it is critical to control for regional heterogeneity in our empirical analysis.

Table 2 presents estimation results for three models that differ from each other in the specification of random effects, capturing regional heterogeneity of diarrhea incidence. Model 1 is a standard logit regression. Model 2 allows for random effects in the intercept (i.e. the random-intercept logit model), and Model 3 additionally allows for random effects in the estimate of reliability indicators (i.e. random-coefficient logit model). Likelihood ratio tests of these regressions indicate that the random-intercept and random-coefficient logit models outperform the standard logit model. The Akaike and Bayesian information criteria (AIC and BIC) indicate that the specification of Model 3 better fits the data relative to Model 2, so we report the magnitude of the effects for our preferred specification. Yet, the results are robust across all model specifications.

As predicted, results indicate that having RELIABLE service significantly reduces the probability of reporting diarrhea incidence by 32.9% relative to no service. Correspondingly, if access to piped water is the key determinant of the beneficial effects on health, one would expect to find a similar, or slightly weaker, negative effect of UNRELIABLE on diarrhea incidence; however, we observe no significant effect. That is, there is no statistical difference in diarrhea incidence between children with unreliable services and those without access to piped water. With respect to individual, household and residential characteristics, we observe a 15% lower probability of diarrhea incidence for females compared to males, a 12.1% decrease by year of age, and a 21.2% decrease in households whose primary language is Spanish. Moreover, we find that the probability of diarrhea incidence decreases by 19.1% with household access to garbage disposal services, and 27.2% with having a devoted room for a kitchen.

We conduct a number of robustness checks to further validate our results. Table 3 presents the results across each of the three model specifications described above. First, we limit our analysis to the subsample of households with water service connections (UNRELIABLE+RELIABLE only) to contrast the effects of having a continuous water supply against UNRELIABLE service. The conditional sample, evaluated in Table 3, Panel A, yields consistent findings with the full sample. Relative to children in households with unreliable water services, we find a 28.9% decrease in the probability of reporting diarrhea for children belonging to RELIABLE households. This magnitude is on par with the reduction of diarrhea incidence observed relative to no connection in Table 2, and is further evidence that water provision is effective in fighting diarrhea incidence among children only if it is continuous.

In addition, in Panels B and C we consider whether heterogeneity in UNRELIABLE is driving the observed null effect in the full sample. Specifically, we test whether there are differences in the effect of UNRELIABLE across households with few service interruptions, one or two days, versus frequent service interruptions of two weeks or more. If the latter effect dominates the first, then our results demonstrate that extremely poor service and no connection are no different in promoting child health. The average number of days of service interruptions among the UNRELIABLE sample is 11.85 days, with the majority (39%) reporting 7 or fewer days of service interruptions. The rest of the breakdown is as follows: 11% report 8-14 days, 29% report 15 days, and 21% report 15+ days. Due to the large cluster of observations at 15 days, and to keep the treatment group sizes comparable, we limit the number of UNRELIABLE categories constructed to 3. We split our sample into two alternative cases, Panel B) 2 groups: 1-14, 15+ days, and Panel C) 3 groups: 1-7, 8-14, 15+ days, and across each specification we find confirmation of our conclusions from Table 2. We continue to find that the only significant effects are associated with RELIABLE, with insignificant estimates of UNRELIABLE service across each of the INTERRUPT bins, even one week or less. Finally, in Panel D we test whether the results are driven by high interruptions by excluding all households reporting 15+ days of interruptions. Again, we find statistically significant effects of RELIABLE with similar point-estimates of 0.665 to 0.712, and no effect of UNRELIABLE.[2]

[2] A complete table of these regression results is available upon request.

Discussion

While the existing studies on the water-health nexus have evaluated the role of access to water sources, few of them have studied the role of service interruptions. Using a sample of children that is nationally representative of Guatemala, this study estimates the effects of water service reliability on diarrhea incidence among children while controlling for geographical heterogeneity and for characteristics of the children and their household. We present empirical evidence demonstrating that interruptions of water service provision have important implications for public health benefits. Our results suggest that although it may be necessary, access to tap water is not sufficient to promote public health if water service is unreliable, which is consistent with prior studies conducted at the community level (Hunter et al. 2009; Majuru et al. 2011; Jeandron et al. 2015). Moreover, these results may partially explain why previous studies have found scant health benefits from access to piped water (e.g. Waddington et al. 2009), or that benefits are heterogeneous across different locations (Vásquez and Aksan 2015).

One potential mechanism for this effect is that water service unreliability may induce households to store water at home using devices that allow water recontamination, e.g. storage in second-hand barrels (see Vásquez 2016a), in turn increasing the probability of diarrheal disease due to contamination as recently demonstrated in Gunther and Schipper (2013) and Wolf et al. (2014). A second consideration is that households may respond to service interruptions by reducing water usage for personal and home hygiene (Evans et al. 2013; Majuru et al. 2016; Wolf et al. 2014), which may expose children to pathogens that put their health at risk. Water recontamination can also occur in pipelines during periods of low pressure or supply interruption

(Majuru et al. 2016; Wolf et al. 2014; Matsinhe et al. 2014), resulting in similar probabilities of contamination and illness across houses with unreliable or without water service.

Our results offer a clear mid- to long-term policy recommendation. While almost 25% of Guatemalan households are yet to be connected to a water system, improvements in water service reliability are required to fully deliver health benefits of that access. Of our sample of 7,579 children, approximately 26% did not experience a reduction of the likelihood of diarrhea incidence despite having access to piped water because those services were interrupted at least one day in the month prior to implementing the survey. Therefore, to promote health, interventions should focus on improvements in the reliability of water services for all (Brocklehurst and Slaymaker 2015). This includes proper maintenance of existing infrastructure and regular monitoring of water service delivery. Government decisions regarding financing for new projects that increase access to water taps should weigh the benefit of timely but unreliable access against the costs of continued diarrhea incidence and long-term maintenance of inefficient infrastructure. Additionally, in the short term, better communication between providers and users on the anticipated duration of water service interruptions may allow households to better prepare alternatives, reducing the likelihood of using contaminated sources.

The estimated models also identify socio-demographic characteristics that affect diarrhea incidence among children. Our findings indicate reductions in the probability of reporting diarrhea associated with being female, by age, and in households whose primary language is Spanish. These results are consistent with the literature that finds males more susceptible to diarrheal disease due to greater environmental exposure (Melo et al. 2008), and the dual threat of underdeveloped immune systems and high risk of contamination of weaning foods for infants (Lanata 2003). Given that households whose primary language is Spanish are more likely to have received formal education (Edwards 2002, McEwan and Trowbridge 2007), this population may be better equipped to follow public health publications or health promoter recommendations on best practices in hygiene. Additionally, the probability of diarrhea incidence decreases with access to garbage disposal services and having a devoted kitchen, consistent with prior studies on exposure to garbage in the environment (see, for example, Rego et al. 2005) and reduced contamination of food supplies, as in Ferrer et al. (2008) in Salvador, Brazil. Reassuringly our results are similar in the random-intercept and random-coefficient models, which account for any remaining heterogeneity across regions (e.g. access to alternative fresh water sources).

We find no evidence to support the hypotheses that diarrhea incidence decreases with in-home water treatments and access to sanitation services in the form of sewerage systems. Our result is consistent with Vásquez and Aksan (2015) in observing that in-home water treatments (i.e. boiling and treating water with chlorine) are ineffective in reducing diarrhea incidence among children in Guatemala. Vásquez and Aksan (2015) argue this may be explained by recontamination of treated water due to inappropriate storage practices. Our results diverge in that we find no effect of connections to sewerage systems. Vásquez and Aksan (2015), however, do not control for access to garbage disposal services which may confound the effects of sewerage services due to simultaneous provision in some areas. In our sample, approximately 63% of children in households with sewerage system connections had access to garbage disposal services as well. By controlling for garbage disposal services, this study disentangles the effects of different forms of sanitation services.

As any other study, this one is not without limitations. In the survey data used here, information on diarrhea incidence was limited to children aged 0-5. Yet, it would be relevant to analyze the effects of water service interruptions on diarrhea incidence among children older than five years and adults, as continuous episodes of illnesses may have long-term effects on learning and productivity (Case et al. 2005). Those effects may be estimated using the methodology presented in this study. As another logical extension to our analysis, future studies can better identify mechanisms between water service unreliability and diarrhea incidence among children to inform the most effective short run coping strategies until system reliability is improved. Although our survey data does not report household storage practices or the alternative water sources that a household with interrupted supply of piped water might use, future research could consider how households cope with service interruptions of varying lengths and the quality of water storage methods employed.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest: We certify that there is no external funding for this research nor does any participant benefit from the results of the study.

Research involving Human Participants and/or Animals: Our research utilizes secondary data that was previously collected in Guatemala.

Informed consent: Our research utilizes secondary data and thus does not require informed consent.

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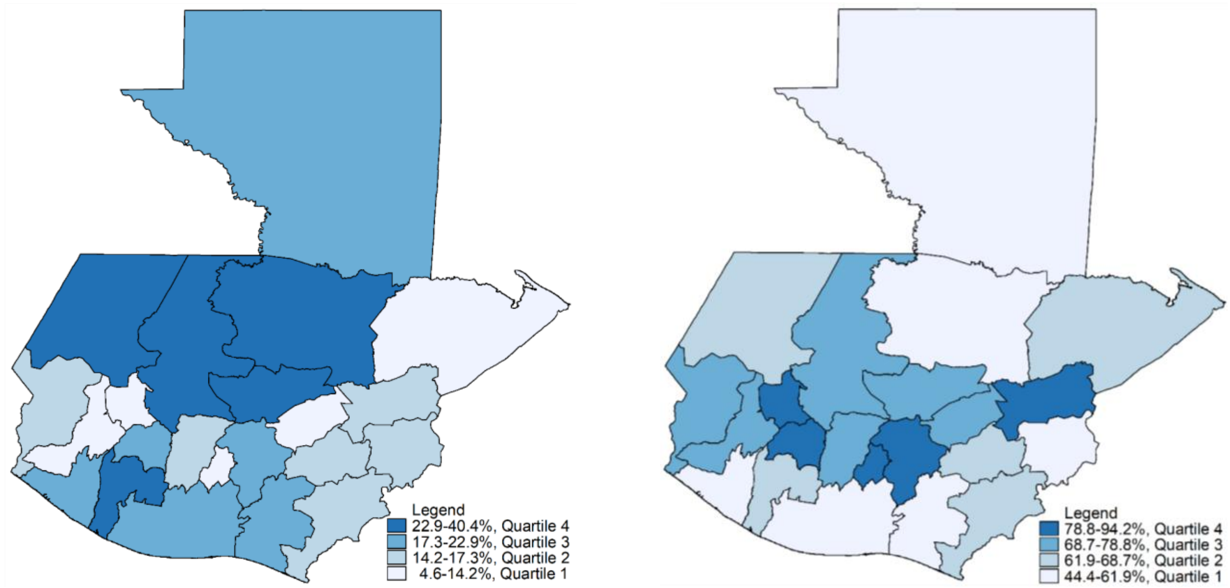
Figure 1. Diarrhea Incidence among Children and Access to Water by Regional Department

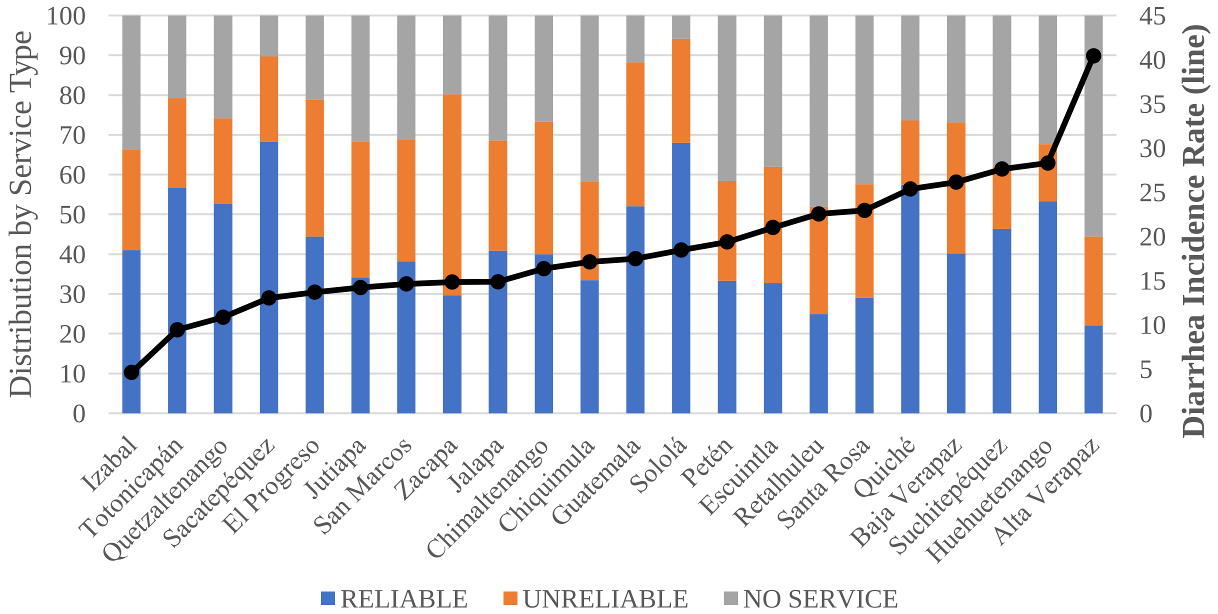
a. Diarrhea incidence b. Access to water



Data Source: 2014 Living Standards Measurement Survey (ENCOVI), Guatemala.

Note: 'Figure a' plots the diarrhea incidence rate for children under 5 across the 22 states of Guatemala. 'Figure b' plots the fraction of children under 5 who belong to a household with a water service connection. The data is split into quartiles from low incidence of diarrhea/low levels of access to water (Quartile 1) to the highest incidence of diarrhea/highest levels of access (Quartile 4).

Figure 2. Distribution of Service Types by Department, Rank Ordered by Diarrhea Incidence Rate



Data Source: 2014 Living Standards Measurement Survey (ENCOVI), Guatemala.

Table 1. Definition and Summary Statistics for Key Variables

	Definition	Pooled		Diarrhea		No Diarrhea	
		Mean	S.D.	Mean	S.D	Mean	S.D
DIARRHEA	If the child had diarrhea in the last month	0.192	0.394	1.000	0.000	0.000	0.000
Water Service Characteristics†							
RELIABLE	If the house had zero days of service interruptions in the last 30	0.439	0.496	0.357	0.479	0.459	0.498
UNRELIABLE	If the house had 1+ days of service interruptions in the last 30	0.264	0.441	0.273	0.446	0.262	0.439
Individual and Household Characteristics							
SEWER	If the house is connected to a sewer system	0.317	0.465	0.259	0.438	0.330	0.470
GARBAGE	If the house uses a municipal or private service to dispose of garbage	0.243	0.429	0.178	0.383	0.258	0.438
BOIL	If the household boils drinking water at home	0.437	0.496	0.483	0.500	0.426	0.494
FILTER	If the household filters drinking water at home	0.037	0.190	0.025	0.158	0.040	0.196
CHLORINE	If the household treats drinking water with chlorine at home	0.128	0.334	0.138	0.345	0.126	0.332
BOTTLED	If the household consumes bottled water	0.168	0.374	0.138	0.345	0.175	0.380
KITCHEN	If the house has a dedicated room for the kitchen	0.634	0.482	0.533	0.499	0.658	0.475
WALLS	If the house has brick or stone walls	0.523	0.500	0.488	0.500	0.531	0.499
ROOF	If the house has a concrete roof	0.110	0.313	0.082	0.274	0.117	0.321
DIRTFLOOR	If the house has a dirt floor	0.380	0.485	0.429	0.495	0.369	0.483
FEMALE	If the child is female	0.483	0.500	0.455	0.498	0.490	0.500
AGE	Age of the child (in years)	2.477	1.704	2.211	1.540	2.540	1.735
PEOPLE/ROOM	Number of people in the household per room	3.820	2.375	4.194	2.551	3.731	2.322
SPANISH	If Spanish is the primary language spoken in the home	0.699	0.459	0.638	0.481	0.714	0.452
RURAL	If the child lives in a rural area	0.626	0.484	0.665	0.472	0.617	0.486
Observations		7579		1453		6126	

Data Source: 2014 Living Standards Measurement Survey (ENCOVI), Guatemala.

Note: With the exceptions of AGE and PEOPLE/ROOM that are continuous variables, each variable is constructed as a dichotomous measure in which 1=Yes, 0=Otherwise. Therefore, the mean value of dichotomous indicators can be interpreted as the proportion of children that fell in the category represented by the corresponding indicator. Their standard deviation is included for completeness and to evaluate the significance across sub-samples. All differences across subsamples are statistically significant, except UNRELIABLE and CHLORINE.

†RELIABLE and UNRELIABLE are compared against a third excluded category of children belonging to households with no water service.

Table 2. Effect of Reliable or Unreliable Water Service on Diarrhea Incidence

	Model 1 Logit	Model 2 Mixed Logit	Model 3 Mixed Logit
Fixed Effects			
RELIABLE	0.709***	0.717***	0.671***
	(0.0558)	(0.0685)	(0.0733)
UNRELIABLE	0.967	0.966	0.948
	(0.0800)	(0.0957)	(0.1078)
SEWERAGE	0.896	0.910	0.932
	(0.0852)	(0.1032)	(0.1090)
GARBAGE	0.781**	0.807*	0.809*
	(0.0817)	(0.0980)	(0.1004)
BOIL	1.138	1.143	1.122
	(0.0995)	(0.1131)	(0.1151)
FILTER	0.839	0.784	0.817
	(0.1617)	(0.1649)	(0.1757)
CHLORINE	1.129	1.105	1.104
	(0.1177)	(0.1286)	(0.1323)
BOTTLED	1.085	1.045	1.036
	(0.1250)	(0.1336)	(0.1362)
KITCHEN	0.720***	0.744***	0.728***
	(0.0481)	(0.0564)	(0.0571)
WALLS	1.120	1.156	1.171
	(0.0940)	(0.1093)	(0.1144)
ROOF	0.897	0.856	0.872
	(0.1067)	(0.1130)	(0.1180)
DIRTFLOOR	0.943	0.944	0.970
	(0.0796)	(0.0897)	(0.0951)
FEMALE	0.867**	0.856**	0.848**
	(0.0524)	(0.0557)	(0.0564)
AGE	0.890***	0.882***	0.879***
	(0.0159)	(0.0168)	(0.0171)
PEOPLE/ROOM	1.027*	1.023	1.023
	(0.0143)	(0.0162)	(0.0168)
SPANISH	0.841*	0.822	0.788*
	(0.0797)	(0.1009)	(0.0970)
RURAL	0.886	0.909	0.902
	(0.0715)	(0.1002)	(0.0977)
CONSTANT	0.545***	0.449***	0.462***
	(0.118)	(0.121)	(0.127)
Random Effects			
UNRELIABLE			0.806*
			(0.108)
CONSTANT		0.611***	
		(0.085)	
χ^2		142.13	147.94
AIC		6927.005	6921.200
BIC		7204.330	7198.525
Observations	7579	7579	7579

Data Source: 2014 Living Standards Measurement Survey (ENCOVI), Guatemala.

Note: The comparison group is households that report no water service. Each model controls for Regional Department fixed effects. Results are presented in Odds-Ratios; standard errors are reported in parentheses, and *, **, and *** indicate significance levels of 10, 5 and 1%, respectively.

Table 3. Robustness tests of the effect of RELIABLE and UNRELIABLE water service

	Model 1 Logit	Model 2 Mixed Logit	Model 3 Mixed Logit
A. Effect of Reliable Water Service, Conditional on Service			
RELIABLE	0.737***	0.721***	0.711***
	(0.0574)	(0.0676)	(0.0754)
χ^2		86.23	89.58
AIC		4635.252	4631.908
BIC		4891.894	4888.549
Observations	5327	5327	5327
B. Heterogeneous Effects of Unreliable Service, 2 Categories			
RELIABLE	0.711***	0.717***	0.672***
	(0.0560)	(0.0685)	(0.0734)
INTERRUPT, 1-15DAYS	0.990	0.964	0.961
	(0.0875)	(0.1017)	(0.1150)
INTERRUPT, 16+ DAYS	0.888	0.977	0.904
	(0.1257)	(0.1587)	(0.1617)
χ^2		141.57	147.49
AIC		6928.998	6923.077
BIC		7213.256	7207.336
Observations	7579	7579	7579
C. Heterogeneous Effects of Unreliable Service, 3 Categories			
RELIABLE	0.708***	0.717***	0.669***
	(0.0558)	(0.0686)	(0.0731)
INTERRUPT, 1-7 DAYS	1.072	1.065	1.056
	(0.1134)	(0.1337)	(0.1477)
INTERRUPT, 8-15 DAYS	0.892	0.848	0.850
	(0.1024)	(0.1148)	(0.1266)
INTERRUPT, 16+ DAYS	0.883	0.967	0.892
	(0.1250)	(0.1572)	(0.1597)
χ^2		141.81	147.31
AIC		6928.684	6923.186
BIC		7219.876	7214.377
Observations	7579	7579	7579
D. Effect of Reliable & Unreliable Service, Excluding Households 15+ Days Unreliable			
RELIABLE	0.699***	0.712***	0.665***
	(0.0562)	(0.0698)	(0.0729)
UNRELIABLE	1.105	1.109	1.104
	(0.1087)	(0.1309)	(0.1443)
χ^2		126.77	123.80
AIC		6060.418	6063.381
BIC		6332.077	6335.04
Observations	6578	6578	6578

Data Source: 2014 Living Standards Measurement Survey (ENCOVI), Guatemala.

Notes: a. Panel A is limited to households that report having water service. The excluded comparison group is UNRELIABLE, i.e. households with 1-30 days of service interruptions in the last 30.
b. Panels B & C utilize the full sample of 7,579 children; UNRELIABLE is split into 2 and 3 categories of 'Days Interruptions,' respectively. The excluded comparison group is no service.
c. Panel D excludes households that report having 15 or more service interruptions in the last 30 days. The excluded comparison group is no service.

Results are presented in Odds-Ratios; standard errors are reported in parentheses, and *, **, and *** indicate significance levels of 10, 5 and 1%, respectively.