Water, Sanitation and Child Health –

Evidence from the Demographic and Health Surveys 1986 – 2007.

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Summary

Background

Despite continued national and international efforts, access to improved water and sanitation remains limited in many developing countries. The health consequences of lacking access to water and sanitation are severe, and particularly important for child development.

Methods

We merge all available Demographic and Health Surveys (DHS) with complete birth histories and water and sanitation information to obtain a cross-sectional data set with 1.1 million children under age 5. The data set covers 171 surveys in 70 low- and middle- income countries over the period 1986 to 2007. We used logistic models to estimate the effect of water and sanitation access on infant and child mortality, diarrhea and stunting.

Findings

Odds ratios for the effect of improved water on infant mortality range between 0.81 and 0.88. Odds ratios for the effect of improved sanitation on infant mortality range between 0.82 and 0.92. For child mortality, improved water and intermediate sanitation technologies do not show any significant effect, while the odds ratio for high quality sanitation are 0.77. For diarrhea, the odds ratios are 0.91-0.92 for improved water and 0.87-0.92 for improved sanitation. The odds ratios for stunting are 0.92-0.97 for water and 0.73-0.88 for sanitation when a full set of controls is included in the empirical model.

Interpretation

While our point estimates are smaller than some of the estimates reported in the existing literature, the results presented in this paper strongly underline the large health costs of lacking access to water and sanitation in low and middle income countries.

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Introduction

Millennium Development Goal (MDG) 4 calls for a reduction of the Under-5 Mortality Rate by two-thirds between 1990 and 2015. A recent review by Murray et al. (2006) suggests that while a number of developing countries are on track to achieve MDG-4, many nations, particularly in sub-Saharan Africa, are unlikely to reach the target. Diarrhea is the second most important cause of under-5 deaths, with the World Health Organization attributing 1.9 million deaths in 2004 to unimproved water supply and unimproved sanitation. The vast majority of these deaths is attributed to diarrheal diseases and affects children under the age of 5 (WHO, 2009).

Improving water supply and sanitation could thus potentially go a long way towards achieving MDG-4 in many countries. In addition, MDG 7, ensuring environmental sustainability, sets a target specifically related to water and sanitation, aiming for a fifty percent reduction in the proportion of people without access to safe drinking water and basic sanitation between 1990 and 2015. A mid-period review indicates generally solid progress towards the target for safe drinking water with the notable exception of sub-Saharan Africa; the overall progress made towards adequate sanitation is much weaker (UNICEF/WHO, 2004). While 83% of the world's population is estimated to have access to improved water supply, only 59% of the population has access to adequate sanitation (WHO, 2009).

Despite the fact that water and sanitation are seen as central to policies to reduce child mortality (a Lancet editorial in 2007 described adequate sanitation as "the most effective public health intervention the international community has at its disposal"), there have been few comparable studies attempting a more comprehensive analysis of the health benefits of improving drinking water and sanitation in developing countries. A meta-analysis of the impact on diarrhea morbidity of water supply, water quality, and sanitation improvements found only six usable studies of effects of water supply, 15 of water quality, two of sanitation and five of combinations (Fewtrell et al., 2005); findings of the meta-analysis were that improved water supply reduced diarrhea morbidity risk (not explicitly defined in some studies) by 25%, improved water quality by 31%, improved sanitation by 32%, and combination interventions by 33%. We have been unable to find comparable meta-studies of the mortality impact of water and sanitation improvement, even though several historical studies suggest that improvements in water and sanitation were instrumental in the declines in infant and child mortality in the 19th and early 20th century (Cutler and Miller (2005); Preston and van de Walle (1978); Szreter (1988); Watson (2006); Woods, Watterson and Woodward (1988; 1989)).

In this paper we use data from a set of broadly comparable nationally-representative household surveys carried out in 70 developing countries since 1986 to produce a systematic evaluation of the relation between household access to adequate water and sanitation and child health. While the cross-sectional nature of the data used complicates matters when it comes to the (causal) interpretation of the estimated effects, the main advantage of the approach chosen in this paper lies in its geographical and temporal scope: rather than measuring the short-term and *local* effects of water and sanitation programs in the geographically focused and closely controlled environments typically studied (see Fewtrell et al. (2005) for an overview) we explore household level variation in a wide array of institutional, geographic and socioeconomic settings to quantify the average child health improvements associated with changes in water and sanitation access in developing countries. In addition to their broad coverage, the main advantage of working with data from the DHS is that they allow us not only to analyze child diarrhea as the most commonly used measure of child health in the area, but also to look at child mortality and stunting as two alternative child health indicators. While the relevance of child mortality appears obvious, it seems plausible that continued exposure to diarrheal diseases will manifest itself in a child's physical development. Conditional on the same housing, family and nutrition conditions, we expect children lacking access to adequate water and sanitation to suffer more frequently from bouts of diarrhea as well as other water and sanitation related diseases, and, as a consequence, to develop more slowly relative to their age cohort. Accordingly, we interpret the height-for-age measure used in our analysis as an indicator for the child's cumulative exposure to health hazards, and use it to identify the medium to long term effects of lacking access to water and sanitation on child development.

Data

The data analyzed in this paper are from the Demographic and Health Surveys (DHS). The DHS's are nationally-representative household surveys largely financed by the United States Agency for International Development and implemented by Macro International in collaboration with national statistical agencies.[1] 173 standard DHS surveys were conducted in 71 low and middle income countries between 1986 and 2007, with a rather comprehensive geographic coverage as illustrated in Figure 1 below. Two surveys, Ecuador 1987, and Cambodia 2005, were dropped from our analysis due to lacking water access information, leaving us with a sample of 1.1 million children in 171 surveys across 70 countries.

For our purposes, the key pieces of information collected by the DHS surveys are the full birth history for every woman in the sample[2], information about the health of each child, and information from the household questionnaire, which contains data on the household's access[3] to water and sanitation, as well as a large set of potentially confounding household characteristics.

The birth history files provide information on child birth and early child survival; each woman is asked for the date of birth (month and year) of each live-born child, the child's sex, whether the child is still alive, and (if the child has died) the age at death (in days if in the first month, in months if between months one and 24, and in years thereafter). These data make it possible to locate child deaths both in time and by age. In addition to the analysis of water and sanitation interactions with child mortality, we also examine two child morbidity measures collected as part of the DHS: child diarrhea, an indicator, which equals one if the child had diarrhea in the two

[1] See *http://www.measuredhs.com/* for further information.
[2] While in general DHS use nationally representative sampling for all women aged 15-49, some countries, such as Bangladesh, restrict the sampling frame to ever-married women.
[3] The DHS survey questionnaire asks household respondents about the "main source" of drinking water as well as the toilet facility members of the households "usually use". Members of the households may thus have access to other water sources or types of sanitation which we cannot observe in survey data.

weeks preceding the survey, and growth retardation (stunting), an indicator equaling one if the child's height is two or more standard deviations below the international standard height tables for a child of that age.[4]

Our main explanatory variables of interest are access to drinking water and sanitation. Most socioeconomic variables in the DHS are standardized in the recode files prior to the public data dissemination. This is, however, not true for the water and sanitation variables, where different categories are used not only across countries, but also across surveys for the same country. In the merged data set, there are 422 different categories for toilet facility, and 556 different categories for the household's source of drinking water. To guarantee comparability of the water and sanitation variables across countries and time, we have constructed categorical variables, dividing both water source and toilet facility access into three broad classes of presumed "quality".[5]

Water source quality was coded as poor if the primary source of water was surface water such as rivers, lakes or standing rain water. The water source was coded as of intermediate quality if the primary source was below the surface, such as all springs, boreholes, standpipes, wells and dug wells but not part of a public piped system. Lastly, water source quality was coded as high if the household reported direct access to piped water or bought drinking water from vendors. Even though it is clearly possible that in some cases water from intermediate quality sources may be less contaminated than water from public piped systems or vendors (especially in the case of deep boreholes), the main presumption of the chosen categorization is that better technology leads, on average, to higher quality water.

Following the same logic, we divided toilet facilities into three broad categories of different presumed "quality": poor if the household reported no access to any toilet facilities; intermediate if the household reported access to a basic or improved latrine; and high if the household had access to a flush toilet. A full list of the categories and classifications is available as a web appendix.

In addition to these key variables, we have included several control variables: the sex and age of the child, whether the child was the result of a multiple birth, the education of the mother and her partner, usual type of place of residence, the number of household residents over the age of 5, household ownership of certain assets (radio, television, bicycle)[6] and whether the mother has a health card for the child (for the estimates of child diarrhea and under-nutrition).

Table 1 shows descriptive statistics across the entire pooled data set. Information about basic child characteristics as well and water and sanitation is available for 1,113,517 children under the

[4] Following a change in the WHO guidelines, the growth standards used in the DHS were changed in 2005; the resulting changes in the stunting categorization are small.

[5] The DHS surveys do not contain detailed information about water and sanitation quality; it should generally be true, however, that better water and sanitation technology is associated with improved water and hygiene conditions.

[6] The DHS surveys contain a long list of household assets, the composition of which varies substantially across time. We have chosen the three assets which were most consistently used; the inclusion of a longer list of assets substantially reduces sample size without adding much to explaining household level variation in water, sanitation and child health.

age of five. Twelve percent of children in the sample live in households with surface water as the primary drinking water source, while 45% have access to a spring or well, and 43% live in households with a high quality water source. The lack of improved sanitation access is even more pronounced: thirty-four percent of children in our sample have no access to any toilet facility at all, while 43% have access to some type of latrine, and only 23% have access to a flush toilet.

With regard to the health outcomes, approximately 30 out of 1000 children die in the first month of life, and about the same percentage in the subsequent 11 months; a smaller 10 per 1,000 die between 12 and 59 months.[7] As explained in further detail in the notes to Table 1, information on child diarrhea and height was only collected in 80% and 60% of the surveys, respectively. For 17% of children with available diarrhea information, mothers reported a diarrheal episode in the two weeks prior to the survey interview. With regard to growth retardation, a staggering 33% of all children in the combined DHS sample were classified as stunted. It should be noted that all statistics displayed in Table 1 represent unweighted sample averages.

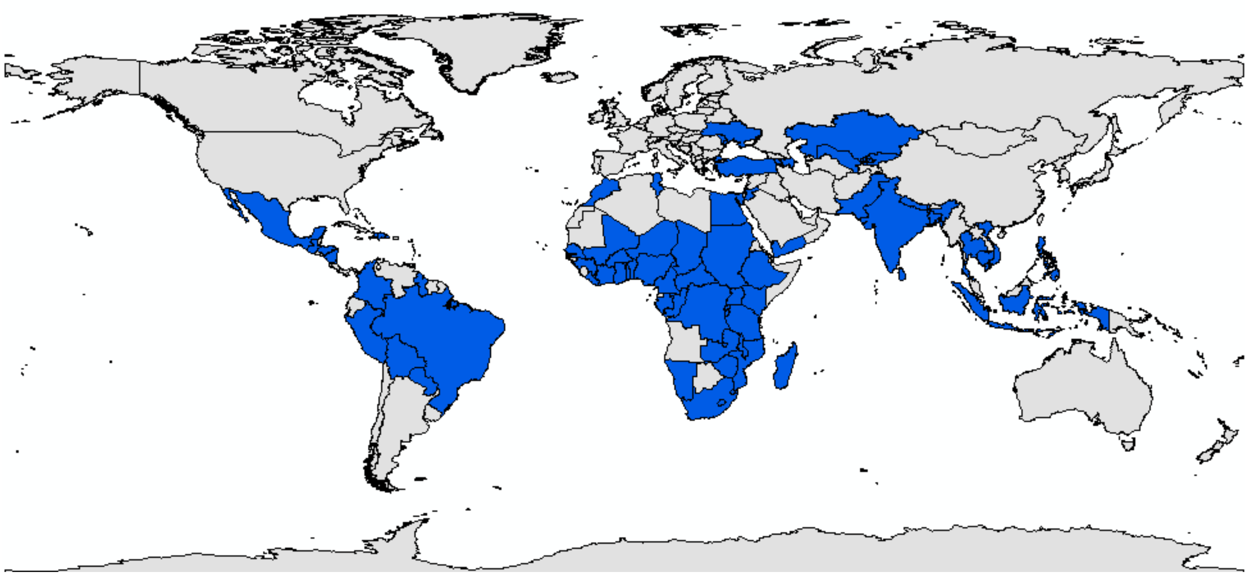

Figure 1: **70 countries that conducted at least one Demographic and Health survey for which data on household access to water and sanitation is available.**

[7] It should be noted that the probability of death of children between 12 and 59 months of age does not correspond to the standard mortality measure (${}_{12}q_{59}$), since we condition our analysis on the child's survival up to age 12 months, but not on being born at least 5 years prior to the interview. Accordingly, the age fixed effects in our empirical specifications represent both changes in mortality over time and differential mortality risk exposure durations across cohorts.

Table 1: Descriptive Statistics

Water and Sanitation	Obs.	Mean	Std.dev.	Min	Max
Intermediate quality water source	1,113,517	0.45	0.50	0	1
High quality water source	1,113,517	0.43	0.49	0	1
Intermediate quality sanitation	1,113,517	0.43	0.50	0	1
High quality sanitation	1,113,517	0.23	0.42	0	1
Basic Child Characteristics	Obs.	Mean	Std.dev.	Min	Max
Female	1,113,517	0.49	0.50	0	1
Multiple birth	1,113,517	0.03	0.16	0	1
Age in years	1,113,517	1.88	1.39	0	4
Health outcomes	Obs.	Mean	Std.dev.	Min	Max
Neonatal mortality	1,113,517	0.03	0.17	0	1
Mortality 1-12 months	1,113,517	0.03	0.18	0	1
Mortality 13-48 months	1,113,517	0.01	0.11	0	1
Diarrhea*	991,485	0.17	0.37	0	1
Stunted**	686,414	0.33	0.47	0	1
Additional controls	Obs.	Mean	Std.dev.	Min	Max
Mother educational attainment	883,003	0.90	0.89	0	3
Partner educational attainment	883,003	1.14	0.93	0	3
Urban residence	883,003	0.33	0.47	0	1
Household members age 5 and over	883,003	5.11	3.28	1	66
Household owns radio	883,003	0.57	0.49	0	1
Household owns tv	883,003	0.32	0.47	0	1
Household owns bike	883,003	0.30	0.46	0	1
Mother has health card for child	883,003	0.75	0.44	0	1

Notes:
* Diarrhea information not available in the Egypt 1988, Guyana 2005, Indonesia 1987, Turkey 2003, and Ukraine 2007 surveys.
** Height for age data not collected in the following surveys: Bangladesh 1993, Brazil 1991, Colombia 1990, Dominican Republic 1999, Guyana 2005, Indonesia 1987, Indonesia 1991, Indonesia 1994, Indonesia 1997, Indonesia 2002, Kenya 1989, Liberia 1986, Pakistan 2006, Peru 1986, Philippines 1993, Philippines 1998, Philippines 2003, Senegal 1997, South Africa 1998, Sudan 1990, Ukraine 2007, Vietnam 1997, Vietnam 2002.

Methods

We run logistic regressions using the Stata© 10 software package with 5 different child health measures as dependent variables: neonatal mortality (the probability of dying in the first month of life), post-neonatal infant mortality (the probability of dying between the first and 11^{th} month of life, conditional on surviving to one month), the probability of dying between ages one and five, conditional on surviving to age 1, the probability of having diarrhea in the two weeks before the survey, and the probability of being stunted. It should be noted that while the stunting and diarrhea variables reflect information at the time of the interview, the child mortality variables reflect mortality over the 5 year period preceding the survey covered in the child recode file. All the regressions control for child characteristics (sex, whether one of a multiple birth, and age for the analyses of mortality between age 1 and age 5, diarrhea and stunting).

Since access to water and sanitation is clearly not randomly assigned to households covered in national representative household surveys such as the DHS,, simple correlations between water and sanitation access and health outcomes are likely to overstate the causal effect of the former on the latter. It seems reasonable to expect that wealthier households, households with more health knowledge and households with stronger health preference are not only more likely to privately invest in water and sanitation, but also to make an effort to use publicly provided infrastructure. To reduce the selection or omitted variable bias generated by the correlation between water and sanitation access and these factors to a minimum, we run regressions with controls for parental educational attainment (separate intercepts for primary, secondary, and tertiary education), urban residence, household size in terms of numbers of household members aged five and over, and household ownership of durable goods as a proxy of the households' long-term income (Filmer and Pritchett, 1998). In an attempt to also control for parental health knowledge and preoccupation with child health we also include an indicator variable for whether the mother has a health card for the child in the child health regressions (stunting and diarrhea regressions only since health card information is not available for deceased children).

Last, we include survey fixed effects to control for unobserved country and time period characteristics specific to a particular survey, which means that we can also exclude country-level differences in income and health as well as infrastructure policies as potential confounders.

The generic logistic model we estimate is given by

$$\ln\left(\frac{p_{ijk}}{1-p_{ijk}}\right) = \beta_0 + \beta_1 Wat_j + \beta_2 San_j + \chi C_{ijk} + \delta_j H_j + \kappa S_k + \varepsilon_{ijk}$$

where p_{ijk} is a dichotomous outcome for child i in household j in DHS survey k, Wat_j is the type of water access of household j, San_j is the toilet facility of household j, C_{ijk} is a vector of child characteristics, H_j is a vector of household physical and human capital variables, and S_k is a survey dummy. Standard errors are adjusted for clustering at the primary sampling unit level.

Results

Table 2 shows the associations of drinking water source and type of toilet facility and mortality risks in the neonatal, post-neonatal and child age ranges. For each outcome variable we show the results of two models: a reduced model which includes only water and sanitation as well as child characteristics and survey fixed effects, and a full specification, which includes parent and household characteristics to reduce endogeneity concerns as discussed above. Higher quality toilet facilities appear significantly protective for all age ranges of children, except for intermediate quality facilities on the mortality risks for children aged 12 to 59 months. For all age ranges high quality sanitation seems to be more protective than basic latrines. Also, for all three cases the estimated protective effects of water and sanitation were smaller once we controlled for household characteristic. The estimated effects are substantial: children living in a household with high quality toilet infrastructure have a mortality risk which is about 15 to 20 percent lower than that of children living in households with no toilet facility. The result that higher quality facilities are more protective than intermediate technologies also appears plausible.

Somewhat contrary to the historical evidence,[8] the results for water access are less clear-cut. Once we control for parental and household characteristics, water access appears beneficial only for children aged between one month and one year. In this group, however, the water effect appears as large as the effect of improved sanitation.

Table 2: Source of Water and Type of Toilet Facility and Child Mortality

Type of Water Source or Toilet Facility	**Neonatal mortality**		**Mortality 1-11 months**		**Mortality 12-59 months**	
	(1)	(2)	(3)	(4)	(5)	(6)
Intermed. quality water	1.032	1.057**	0.886***	0.883***	1.003	1.038
	(0.0206)	(0.0238)	(0.0167)	(0.0183)	(0.0285)	(0.0326)
High quality water	0.893***	0.971	0.721***	0.811***	0.803***	0.966
	(0.0194)	(0.0251)	(0.0154)	(0.0206)	(0.0264)	(0.0377)
Intermed. quality sanitation	0.843***	0.895***	0.806***	0.920***	0.839***	0.967
	(0.0129)	(0.0155)	(0.0126)	(0.0162)	(0.0194)	(0.0254)
High quality sanitation	0.704***	0.854***	0.550***	0.827***	0.489***	0.773***
	(0.0156)	(0.0232)	(0.0144)	(0.0269)	(0.0228)	(0.0440)
Survey fixed effects	YES	YES	YES	YES	YES	YES
Child characteristics	YES	YES	YES	YES	YES	YES
Household characteristics	NO	YES	NO	YES	NO	YES
Observations	1113517	887440	843235	671882	586258	466782

Coefficient estimates displayed are odds ratios. Robust z-statistics in parentheses. Standard errors are clustered at the survey cluster level. All specifications include survey fixed effects and controls for child sex, and multiple births. Columns 2, 4, and 6 also control for mother's educational attainment, mother's five year age group, urban residence, household size, household assets, partner's educational attainment.
*** p<0.01, ** p<0.05, * p<0.1

Table 3 shows the associations of drinking water source and type of toilet facility and indicators of child health for surviving children. The dependent variables are indicator variables for the child having had an episode of diarrhea in the two weeks before the survey, and for the child being stunted, respectively. As before, we show results for a reduced model, which excludes

[8] Cutler and Miller (2005) argue that the health improvements generated by investment in sanitation infrastructure are small when compared to the improvements generated by centralized water supply.

parental and household characteristics, and a fully specified model. Once again, all models include controls for child characteristics and survey fixed effects.

Our results imply that both access to water and sanitation have positive effects on child health. Children in households with access to a high quality water source have risks of diarrhea and of being stunted roughly 10 percent lower than children in households with low quality water access, with intermediate quality falling somewhere in between for both outcomes. The point estimates for sanitation are even larger. The results from columns (2) and (4) of Table 3 suggest that children in households with access to high quality sanitation have a 13% lower chance of suffering from diarrhea in the short run, and are nearly 27% less likely to be stunted, with a reduction of 12% even for intermediate quality sanitation.

Table 3: Source of Water and Type of Toilet Facility and Child Health

Type of Water Source or Toilet Facility	**Diarrhea in past 2 weeks**		**Stunted (height < median-2sd)**	
	(1)	(2)	(3)	(4)
Intermediate water quality	0.923***	0.923***	0.919***	0.971**
	(0.0110)	(0.0122)	(0.0107)	(0.0121)
High water quality	0.868***	0.908***	0.688***	0.915***
	(0.0109)	(0.0135)	(0.00868)	(0.0131)
Intermed. quality sanitation	0.885***	0.921***	0.718***	0.882***
	(0.00791)	(0.00947)	(0.00653)	(0.00863)
High quality sanitation	0.742***	0.871***	0.406***	0.731***
	(0.00918)	(0.0135)	(0.00519)	(0.0107)
Survey fixed effects	YES	YES	YES	YES
Child characteristics	YES	YES	YES	YES
Household characteristics	NO	YES	NO	YES
Observations	989188	796557	686414	567011

Coefficient estimates displayed are odds ratios. Robust z-statistics in parentheses. Standard errors are clustered at the survey cluster level. All specifications include survey fixed effects and controls for child age, sex, and multiple births. Columns 2, 4, and 6 also control for mother's education level, mother five year age group , urban residence, household size, household assets, partner's educational attainment, child age in years, and for whether the mother holds a health card for the child at the time of the interview.
*** p<0.01, ** p<0.05, * p<0.1

Discussion

This analysis of the associations between child health outcomes and source of household drinking water supply and type of toilet suggests strongly protective effects, particularly for high quality toilets. The effects of improved sanitation are broadly speaking similar both for child mortality and child morbidity outcomes, are robust to the inclusion of controls for human and physical capital of the household, and do not seem to vary markedly by age of the child. The effects of improved water infrastructure on child mortality are a bit more nuanced and significant only for children between the ages of 1 and 12 months. This result is consistent with the notion that the period of highest risk of poor quality water coincides with weaning, which generally happens before the child's first birthday. The effects of improved water supply on child morbidity outcomes are significant, robust to the inclusion of controls for human and physical capital of the household, and are of similar magnitude for both diarrhea episodes and stunting risk.

One of the most robust findings in analyses of factors associated with child health and mortality risks is a persistent and large protective effect of maternal (and to a lesser extent partner) education (Hobcraft et al. (1984), Rutstein (2000)). The magnitude of the water and sanitation effects shown in our analysis can thus be appreciated by comparing coefficients of the water and sanitation variables with the coefficients in the same models of various levels of maternal and paternal (or partner) education. Table 4 shows coefficients for four categories of maternal and paternal education (the omitted category is no education) for the five outcome variables studied; the results in all cases are of course controlling for parental and household characteristics. As would be expected from the literature, maternal education is strongly protective for all the outcomes and the protective effect increases with the level of education. In general, the protective effect of maternal education on mortality is smallest in the neonatal period and increases with age range of child, tends to be smaller on diarrhea risk than on mortality, and is very similar between mortality and stunting. Patterns for partner education are broadly similar to those for the mother, but generally smaller.

Table 4: Child health and parental education

	Neonatal Mortality	**Mortality 1-12 months**	**Mortality 13-48 months**	**Diarrhea**	**Stunted**
	(1)	(2)	(3)	(4)	(5)
Mother primary	0.924***	0.900***	0.894***	1.024**	0.848***
	(0.0172)	(0.0166)	(0.0246)	(0.0101)	(0.00785)
Mother secondary	0.826***	0.629***	0.584***	0.905***	0.622***
	(0.0207)	(0.0181)	(0.0271)	(0.0116)	(0.00771)
Mother tertiary	0.673***	0.411***	0.394***	0.734***	0.398***
	(0.0369)	(0.0322)	(0.0565)	(0.0181)	(0.0109)
Partner primary	0.992	0.916***	0.937**	1.004	0.951***
	(0.0187)	(0.0170)	(0.0268)	(0.0104)	(0.00918)
Partner secondary	0.912***	0.808***	0.800***	0.957***	0.788***
	(0.0200)	(0.0188)	(0.0290)	(0.0113)	(0.00872)
Partner tertiary	0.848***	0.610***	0.643***	0.855***	0.665***
	(0.0332)	(0.0309)	(0.0524)	(0.0163)	(0.0128)
Survey fixed effects	YES	YES	YES	YES	YES
Child characteristics	YES	YES	YES	YES	YES
Household characteristics	YES	YES	YES	YES	YES
Observations	887440	671882	466782	796557	567011

Coefficient estimates displayed are odds ratios. Robust z-statistics in parentheses. Standard errors are clustered at the survey cluster level. All specifications include the water and sanitation variables, survey fixed effects and controls for child age, sex, and multiple births. Columns 2, 4, and 6 also control for mother's education level, mother five year age group , urban residence, household size, household assets, partner's educational attainment, child age in years, and for whether the mother holds a health card for the child at the time of the interview.
*** p<0.01, ** p<0.05, * p<0.1

Relative to the point estimates obtained for maternal education, the protective effect of an intermediate or high quality toilet tends to fall somewhere between the protective effect of primary and secondary maternal education and high quality toilet is more protective than partner secondary education. Effects of improved water supply are generally smaller than those of maternal primary education, but those of high quality water generally exceed the effects of partner primary education.

Clearly, some caveats are in order here. First, while we include a large set of parental and home environment controls in our main specification to reduce the risk of omitted variable (selection) bias, we cannot completely rule out residual correlations between unobservable household characteristics and both our child health and water and sanitation variables. If these unobservable household characteristics happen to reduce the risk of bad health outcomes, and to also positively correlate with our water and sanitation variables, we might overestimate the effects of water and sanitation even in our fully specified model. Second, given the medium-term approach chosen in our stunting and mortality regressions, one may wonder if parental water and sanitation choice may respond to observed health outcomes. While it seems rather implausible that parents decide to invest in water and sanitation in response to a single bout of diarrhea, it may well be possible that continued observation of children being sick or, even more so, experiencing a child death in the family (potentially attributable to poor water and sanitation) may induce parents to change their primary access point. To the extent that this was true, we would underestimate the true effects of water and sanitation, as parents with particularly bad health records self-select into the high-quality water and sanitation groups. Last, and maybe most importantly, there is clearly some noise in the coding of our water and sanitation variables. As discussed before, our water and sanitation variables are only proxies of the actual conditions faced by children in the household, so that both water and sanitation quality are likely to be measured with substantial error in our data set; the resulting attenuation bias skews the expected distribution of estimates towards zero, leading to an expected underestimation of the true magnitudes. While it is hard to quantify, and even harder to rule out, these potential biases in any observational study, the direction of the overall bias does not appear obvious in the analysis presented here. The fact that our point estimates are slightly below coefficients found in randomized trials (see, e..g. Fewtrell et all. (2005)) appears credible, and may be interpreted as evidence for decreasing marginal impacts of water and sanitation investment as programs are scaled up and have to be sustained over time. The fact that estimation results appear highly consistent across health measures and strictly increase with the quality of water and sanitation infrastructure can be viewed as further evidence for the robustness of the presented results, and their implications regarding the health effects of water and sanitation investment.

Conclusion

We analyze the associations between water and sanitation and child health indicators across 70 countries and 171 household surveys conducted as part of the Demographic and Health Surveys. Controlling for as many potentially confounding characteristics of child, the mother and the household as possible, we find strongly protective effects of improved toilet facilities for neonatal, post-neonatal and child mortality risks, as well as for risks of episodes of diarrhea and for stunting; in magnitude, the effects fall somewhere between the protection offered by primary and secondary maternal education. Benefits of improved water are in general smaller, but for mortality appear most strongly in a risk period between one month and one year in which weaning is most likely to occur.

Improved water and sanitation are targets for MDG-7, as well as potentially contributing to achievement of MDG-4. However, a mid-term assessment found that progress on water and especially sanitation was not sufficient to reach the MDG-7 target in most sub-Saharan African countries, where 64% of households do not have access to basic sanitation, and 42% lack safe drinking water (WHO and United Nations Children's Fund 2004). Of the US$ 90 billion of development aid disbursed by international donors in 2006, US$ 3.9 billion (4.3%) was invested in the improvement of water supply and sanitation (OECD, 2008). The evident benefits of (particularly) improved sanitation, the area which has lagged most, make a renewed thinking about investments in such projects an urgent priority.

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