Environment for Development

Discussion Paper Series

April 2011 ■ EfD DP 11-02

Use of Anthropometric Measures to Analyze How Sources of Water and Sanitation Affect Children’s Health in Nigeria

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Environment for Development

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Sunday Olabisi Adewara and Martine Visser

Abstract

We used 2008 DHS data sets to construct child height- and weight-for-age Z-scores and used regression analysis to analyze the effects of different sources of drinking water and sanitation on child health outcomes in Nigeria. We also calculated the probability of a child being stunted or underweight as our measure of malnutrition among children aged 0–59 months. Our results show that both child height and weight Z-scores are positive and significantly related to access to borehole and piped water, and negative and significant for well water. The probabilities of a child being stunted or underweight are both significantly lower for children drinking borehole or piped water, whereas well water has a positive and significant effect on these measures of child health.

Children's access to flush toilets is positive and significantly related to child height- and weight-for-age Z-scores, but the same measures are negatively related to children's use of pit latrines. In line with this, the probability of a child being stunted or underweight is negative and significantly related to access to flush toilets, but positively related to pit latrines. Our results suggest that increasing access to, or providing, safe drinking water and flush toilets for households will significantly reduce the high incidence of malnutrition and water-borne diseases among children in Nigeria and should be a high priority for policymakers.

Key Words: water, sanitation, weight-for-age Z-scores, height-for-age Z-scores, stunting, underweight, child, Nigeria

JEL Classification: D6, I1, I12, I21, Q5

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Use of Anthropometric Measures to Analyze How Sources of Water and Sanitation Affect Children's Health in Nigeria

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The safety and accessibility of drinking water are major concerns throughout the world. Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards. Improving access to safe drinking water can result in tangible improvements to health.

– UN Water Initiative (2010)

Lack of access to safe water and adequate sanitation puts children at high risk of not living beyond his/her fifth birthday, but those who survive serious illness (due to water-related diseases) often do not reach their full physical, intellectual, and social potential due to the effects of poor health care and nutrition.

– UNICEF (2010)

Introduction

Access to safe drinking water and improved sanitation is essential for healthy life and can significantly reduce public expenditure on preventable diseases and epidemics (e.g., cholera, diarrhea, typhoid, and dracunculiasis[1]) arising from contaminated drinking water and unhygienic disposal of human waste. According to the World Health Organization, about 1.7 million deaths annually are related to drinking unsafe water and poor disposal of wastes (WHO 2007). Children are the most vulnerable, due to their low natural immunity, and a high percentage of infant mortality and morbidity is linked to contaminated water and lack of hygienic sanitation. Various studies in different countries have shown that the quality of drinking water is positively associated with reductions in diarrhea and mortality (Cutler and Miller 2005; Clasen et al. 2007; Arnold and Colford 2007; Kremer et al. 2009).

Recent research also shows that drinking unsafe water and poor disposal of waste affects the growth rate of children and may eventually determine their intellectual and physical

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[1] Also known as guinea worm infection.

contribution to economic development (Kingdon and Monk 2010; Deaton 2008; WHO 2007). Over 1.1 billion people worldwide, most of them in developing countries, lacked access to safe drinking water in 2007 (UNDP 2008; WHO 2007).

In this paper, we looked at how access to different sources of drinking water and sanitation affects Nigerian children's height- and weight-for-age Z-scores. We focused on the effects of drinking water from different sources on children's health, particularly given the low quality of well water in Nigeria. A study of six hydrostratigraphic zones[2] in the country shows that the water in about 84 percent of wells has highly concentrated nitrate, which has severe adverse effects[3] on human health (Adelana and Olasehinde 2003; 2008).

Nigerian children below the age of 5 years make up about 17 percent of the 1.8 million deaths due to poor sanitation globally (*Effizee.com* 2010). In 2010, 11 states in Nigeria battled an extended cholera epidemic; of nearly 40,000 cases reported from January–October 2010, some 1,500 were confirmed dead[4] (*NigerianBulletin.com* 2010; UN News Centre 2010). Between 1999 and 2008, over US$ 6 billion of public funds has been devoted to the provision of safe drinking water, improved sanitation, and health-related services by the federal government, excluding contributions by states and local governments (CBN 2009). What is not clear, however, is the quality of water the government has been providing and its effects on the health outcomes of children. In this paper, we specifically try to establish the relationship between households' access to safe drinking water (piped and borehole water) and level of sanitation to the health outcomes of children in Nigeria. We want to offer some insight into how well the public expenditures for drinking water and sanitation are benefiting Nigerian citizens, especially the children. Previous studies on the effects of water and sanitation on children's health outcomes have not been conclusive and we are not aware of any such study for Nigeria (Christiaensen and Alderman 2004; Strauss and Thomas 1995).

Nigeria is the most populated country in Africa with an estimated 150 million people. Although the country is rich in both human and natural resources, about 71 percent of the

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2 Hydrostratigraphy is a branch of geology studying rock layers and stratification.

3 Some of the effects of high intake of nitrate include infant methemoglobinemia (nitrate causes hemaglobin to oxidize, becoming methemaglobin, which cannot bind oxygen), hypertension, "hot dog headache," (headache and flushing seen as a reaction to eating meats heavily preserved with sodium nitrite), cancers, birth defects, and spontaneous abortions (Adelana and Olasehinde 2003).

4 According to the UN News Centre, the outbreak in 2010 was considered the worst in recent years.

population lives on less than $1 dollar per day and about 92 percent on less than $2 dollars per day. It has the second highest maternal mortality rate and mortality of children under five years—about 1 million children annually (191 per 1,000 children). Infant mortality is as high as 86 per 1,000 live births (UNICEF.org n.d.).

In terms of human development, the United Nation Human Development Index ranked Nigeria 158 out of 177 countries in 2007. The 2010 theme of the UN's annual water day, "Clean Water for a Healthy World," speaks volumes about the importance of safe drinking water across the globe. However, about 42 percent of Nigeria's population has no access to clean drinking water—which is almost 20 percent of all people Africa in the same straits (WHO/UNICEF 2010; 2008; UNDP 2010). The implication is that African children are exposed to deadly but preventable water-borne diseases, which affects their growth and health in general (Kingdon and Monk 2010).

Regarding sanitation, none of the successive governments in Nigeria have taken responsibility for providing sanitation services to its citizens. Most houses are built without toilet facilities in both rural and urban areas. It is rare to find rural houses with personal toilets, and urban houses with 50 or more tenants may share one toilet. In 2008, the government, for the first time, promised to construct 1 million public latrines across Nigeria to serve more than 150 million people, but these needed facilities have not yet materialized.

The majority of the poor who struggle to survive do not consider access to a toilet as crucial, yet diarrhea remains the second largest cause of children's deaths in Nigeria (UN Water Initiative 2010). In the 1980s, during military control, sanitary workers were responsible for monitoring household sanitation both in rural and urban areas, but due to shifts in government priorities this service was discontinued by the new regime.

This paper makes four main contributions to the literature. First, to the best of our knowledge, all other studies have used the incidence of diseases to explain child health outcomes in Nigeria: ours is the first to employ anthropometric measures. The nonmonetary measure of malnutrition is not affected by the problem of reliable deflators often associated with other methods. Second, our study is the first to examine the effects of different sources of drinking water at the household level on the health outcomes of children below the age of five years in Nigeria. This is significant, considering the high infant mortality associated with contaminated drinking water. Third, this paper also differs from previous studies because we use both height- and weight-for-age Z-scores to determine the probability of stunted growth and underweight, respectively, as proxies for malnutrition in the country. While stunted growth is a measure of chronic malnutrition, being underweight is a measure of general malnutrition (Silva 2005). Last, this paper is the first to separately examine the effects of sanitation (pit latrines and flush toilets) on the probability of stunted growth and underweight in children in Nigeria.

1. Literature Review

Several studies have attempted to analyze the effects of access to clean water, improved sanitation, and other socioeconomic factors on children's health outcomes using a variety of measures. Most of these studies used either infant mortality or incidence of diarrhea as measures of child health outcomes. These studies could not examine the effects of access to water and sanitation on children's height and weight because the anthropometric measures are only now available through DHS (Demographic and Health Surveys) datasets and the WHO Child Growth Standards.[5]

In their review, Esrey et al. (1991) attributed a 17 percent reduction in the incidence of diarrhea to children's access to improved water supply, and a further 22 percent reduction with better sanitation. In another meta study, Fewtrell et al. (2005) also reported a 25 percent reduction in illness with access to improved water and 32 percent reduction with better sanitation. Waddington et al. (2009), on the other hand, showed that improved sanitation led to a reduction of 37 percent in the incidence of diarrhea, but saw no significant effect from improved water accessibility.[6]

Esrey (1996) used DHS datasets in a cross-country analysis of eight countries. His study established a 13–44 percent reduction in diarrhea with access to flush toilets and an 8.5 percent reduction with latrines. He concluded that access to good sanitation has greater effects on health than access to good water. However, Gunther and Fink (2010) faulted this study because it included only 8 countries of the 63 countries with available DHS datasets in 1995. In response to this shortcoming in Esrey (1996) and the availability of new datasets, Gunther and Fink (2010) used 172 datasets from 70 countries to analyze the effects of access to water and sanitation on infant mortality and morbidity. Their cross-country analysis showed that access to improved

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[5] http://www.who.int/childgrowth/en/

[6] Esrey's (1991) meta study looked at 144 empirical studies on the effects of water and sanitation on health, Fewtrell et al. (2005) reviewed 46 studies, and Waddington et al. (2009) researched 71 studies. They all compared previous empirical studies on the effects of access to sanitation and safe water on the incidences of diarrhea.

water *and* sanitation reduced the incidence of diarrhea in children less than five years by 5–17 percent and showed a 5–20 percent reduction in infant mortality.

While empirical studies on the effects of access to sanitation and water are rare in developing countries, there are some historical retrospective studies. For instance, Woods, Watterson, and Woodward (1988) related reduced infant mortality in both England and Wales in the 19th century to an increase in access to improved water and sanitation. In a similar study in the United States, a 50 percent reduction in infant mortality in the 20th century is attributed to improved water and 75 percent reduction is attributed to accessibility of sanitation (Cutler and Miller 2005). However, Gunther and Fink (2010) observed that it is very difficult to establish causal relationships in these studies because their historical retrospective may not account for some unobservable variables at that time.

Dasgupta (2004) analyzed diarrhea morbidity in the slums of Delhi. His result showed that access to piped water reduces the probability of the incidence of diarrhea. Surprisingly, however, he concluded that access to sanitation and education of the household head has no significant effect on illness. In another study in India, Jalan and Ravallion (2003) examined the effects of access to water on the incidence of diarrhea in children. Their analysis showed that access to piped water reduced the incidence of diarrhea, but the result is sensitive to families' income and education of mothers. Other studies that use diarrhea as the measure of health in relation to access to water include Bozkurt et al. (2003), Van der Hoek et al. (2001), Rao et al. (1998), and Alberini et al. (1996).

However, the above studies do not specifically focus on children's growth rates. Skoufias (1998) used 1994 cross-sectional data to analyze the effect of environmental and socioeconomic factors on the growth of children between ages 0 and 5 years in Romania. His measures of children's health outcomes are height- and weight-for-age Z-scores. His results, however, are not conclusive, but he found that poor sanitary conditions are negatively related to children's health.

Kabubo-Mariara et al. (2008) used DHS datasets from Kenya to analyze the determinants of children's nutritional status. Surprisingly, their results showed that children's growth is either insignificant or negatively related to access to water, measured by cluster shares of households with piped water. On the other hand, children's height has a negative relationship to the share of cluster households with access to traditional toilets, but stunted growth is positively related to access to traditional toilets. This result contradicts Silva's (2005) findings in Ethiopia, where access to water and sanitation was found to have positive effects on children's height and weight. The effect may partly depend on the quality of safe drinking water that households use. While

Kabubo-Mariara et al. (2008) used cluster shares of households with access to piped water and sanitation, Silva (2005) used both individual and community access to water and sanitation. Mangyo (2008) studied the effects of access to water on children's health in China using a dynamic panel model. His results showed that access to in-yard water sources only improved children's health when their mothers are educated. He concluded that the effects of access to water on child health are inconclusive.

2. Empirical Model Specification

Like previous studies on the relationship between environmental variables and child health outcomes (Skoufias 1998; Kabubo-Mariara et al. 2008; Jalan and Ravallion 2003; Khanna 2008), our model is based on the theories of human capital investment, as well as the household production function as specified by Kabubo-Mariara et al. (2008). A household is faced with a utility function, U, which depends on the consumption of a vector of commodities, X, and a vector of leisure, L:

$$U=u(X, L) \tag{1}$$

The household production function for the goods consumed depends on a vector of inputs supplied by the household. A rational household chooses an optimal consumption bundle, given that the production function and the budget constraint do not exceed total income. The assumption of perfect substitution between home production and market goods in the household model is further relaxed to model human capital outcomes because most human capital outcomes cannot be purchased in the market. Other considerations in the household production function are the influence of biological, demographic, and economic factors.

A typical child's health outcome is a product of the biological production function, which is affected by the household's decisions on inputs, such as nutrient intake and general care. The ability of each household to maximize the health of a child depends on available resources and the information constraints facing them. Equation (1) is therefore modified to include a health outcome measure, namely, the supply of growth Y for each child in order to model child health outcome. It is assumed that good health is desirable in its own right and that other reasons are the basis for household decisions on consumption (Kabubo-Mariara et al. 2008). A modification of equation (1) based on the above assumption is:

$$U=u(X, L, Y)\,. \tag{2}$$

Thus, our budget constraint is modified to include child health production function inputs. The constrained utility function is then solved for optimal quantities of child health supplies into the market. In this framework, the reduced form function for each child's health supply is:

$$Y_i = f\,(X_i, X_e, X_h, U_i)\,. \tag{3}$$

Equation (4) is a linear regression function of equation (3):

$$Y_i = \alpha + \beta_1 X_i + \beta_2 X_e + \beta_3 X_h + U_i\ , \tag{4}$$

where Y_i is the child's health outcomes represented by height- and weight-for-age Z-scores, respectively. X_i is a vector of child-specific characteristics, such as age, birth order, gender, single birth (an only child), and multiple births (child has siblings). X_e is a vector of environmental variables, in this case including piped water, borehole water, and sanitation (Kabubo-Mariara et al. 2008; Jalan and Ravallion 2003; Khanna 2008). X_h is a vector of household-specific characteristics, such as education of parents, household assets, mother's years of education, and size of the household. U_i is the effect of unobservable variables on the child's health, which is assumed to be uncorrelated with the regressors (Sahn and Stifel 2002a; 2002b; 2003a; 2003b; Kabubo-Mariara et al. 2008)

3. Measuring Children's Height and Weight

We constructed Z-scores for children's height and weight by using the WHO Child Growth Standards.

Height-for-age Z-score: $\mathrm{Z} = \frac{H - MH}{\sigma}$,

where H is the measured height of the child, MH is the age- and gender-specific median heights of a well-nourished child, and σ is the standard deviation of height of a well-nourished child.

Weight-for-age Z-score: $\mathrm{Z} = \frac{Y - X}{\sigma}$,

where Y is the child's specific measured weight, X is the age- and gender- specific median weights of a well-nourished child, and σ is the standard deviation of weight of a well-nourished reference child.

4. Hypotheses

We approached our study with two basic hypotheses. One, there is a positive relationship between the quality of drinking water and sanitation that children are exposed to and their height- and weight-for-age Z-scores. Access to piped water, borehole water, and flush toilets should therefore have a positive effect on children's health outcomes. Conversely, the effects of well water and pit latrines on these health outcomes should be negative.

Two, in line with the first hypothesis, greater access to safe drinking water and hygienic sanitation facilities will negatively impact the probability of stunted growth and being underweight in children.

5. Data Sources and Method of Estimation

Our main source of data is the 2008 DHS datasets on households' access to water and sanitation in Nigeria. The datasets contain information about children aged 0–5 years in each household, including their weight and height. It also contains information about the parents and the socioeconomic characteristics of the household. We also used the WHO Child Growth Standards for our analysis, plus the age- and gender-specific median weight and height (and their standard deviations) of a well-nourished child.

We first adjusted for the sampling methods and then used OLS (ordinary least squares) regressions to analyze the effects of access to water and sanitation on children's height- and weight-for-age Z-scores. (See results in tables 1 and 2 below, columns 1 and 2.) We further analyzed the probability of a child being stunted and underweight, using survey probit regression methods. By adjusting for the sampling methods, we controlled for the effects of sample design to collect the primary data: sampling weights, clustering, and stratification (Statacorp 2009). Failure to account for sampling weights, according to Kabubo-Mariara et al. (2008), will affect standard errors and yield-biased estimators; in addition, if clustered observations are not independent, using OLS may result in very small standard errors.

DHS data collection is not a purely random sampling because different groups of clusters are separately sampled. The solution to this problem is to apply survey regression techniques to the data in order to produce the correct standard errors (Kabubo-Mariara et al. 2008), as we did. More simply, we estimated the marginal effects of the independent variables on the dependent variable for our probit regressions.

We analyzed the effects of households' access to safe drinking water and sanitation on the probability of children being stunted and underweight. A child is considered stunted if his or her height-for-age Z-score is less than -2, and underweight if the weight-for-age Z-score is less than -2. Our dummy variable for stunting is 1 if a child's height-for-age Z-score is less than -2, and 0 otherwise. The dummy variable for underweight is 1 if the weight-for-age Z-score is less than -2, and 0 if it is greater than -2. This is the international child growth standard recommended by WHO and used by most studies (Kabubo-Mariara et al. 2008; Khanna 2008; Silva 2005; Skoufias 1998). We used survey probit regressions to estimate the probability of a child being stunted and underweight.

6. Regression Results

We divided the regression results and analysis into two parts: height (table 1) and weight (table 2). In columns 2 and 4 in both tables, we substituted well water for piped and borehole water to test for robustness. In table 1, column 1, we examine the effect of a household with access to safe drinking water (piped and borehole water) and sanitation on a child's height-for-age Z-score. The results show that the age of the child, male dummy, multiple births (siblings), and the child's birth order are all negatively related to chronic malnutrition. This result is consistent with Kabubo-Mariara et al. (2008). Age in months, the male dummy, and multiple births are inversely related to the height-for-age Z-score of a child; this finding is statistically significant at the 1 percent level. Young children are thus less likely to be stunted when fed with sufficient breast milk as a newborn. However, as a child's age in months increases, weaning and less breast milk makes them more vulnerable to malnutrition. Our findings indicate that a child's height is likely to be 0.02 Z-scores less as age in months increases, and the probability of stunting in column 3 increases by about 0.008 points. The height-for-age Z-score of a boy is likely to be 0.22 less than that of a girl.

Table 1. Effects of Different Water Sources and Sanitation on Children's Height

Independent variables	***Column 1*** **Height Z-score**	***Column 2*** **Height Z-score (well water)**	***Column 3*** **Probit marginal effects**	***Column 4*** **Probit marginal effects (well water)**
Age in months	-0.0214***	-0.0214***	0.00808***	0.00809***
	(0.00101)	(0.00101)	(0.000648)	(0.000648)
Male dummy	-0.223***	-0.222***	0.128***	0.128***
	(0.0323)	(0.0322)	(0.0202)	(0.0201)
Multiple births (child with siblings)	-0.179**	-0.179**	0.117**	0.117**
	(0.0710)	(0.0708)	(0.0457)	(0.0458)
Birth order	-0.0682***	-0.0685***	0.0504***	0.0506***

	(0.0126)	(0.0126)	(0.00697)	(0.00699)
Piped water	**0.138****		**-0.0659**	
	(0.0650)		**(0.0421)**	
Borehole water	**0.258*****		**-0.162*****	
	(0.0532)		**(0.0325)**	
Pit latrine	**0.0630**	**0.0628**	**-0.0127**	**-0.0122**
	(0.0512)	**(0.0511)**	**(0.0292)**	**(0.0291)**
Flush toilet	**0.566*****	**0.556*****	**-0.311*****	**-0.302*****
	(0.0688)	**(0.0693)**	**(0.0461)**	**(0.0461)**
Mother’s height	0.0333***	0.0333***	-0.0195***	-0.0195***
	(0.00307)	(0.00308)	(0.00188)	(0.00188)
Wealth index	0.0173	0.0175	-0.00163	-0.00173
	(0.0131)	(0.0131)	(0.00704)	(0.00701)
Household size	-0.0139**	-0.0138**	0.00564*	0.00559*
	(0.00644)	(0.00645)	(0.00316)	(0.00315)
Mother’s age	0.0302***	0.0304***	-0.0212***	-0.0213***
	(0.00446)	(0.00446)	(0.00253)	(0.00254)
Parent education	0.0852***	0.0838***	-0.116***	-0.115***
	(0.0158)	(0.0157)	(0.0139)	(0.0139)
Well water		**-0.224*****		**0.136*****
		(0.0475)		**(0.0288)**
Constant	-6.847***	-6.623***	3.123***	2.988***
	(0.494)	(0.499)	(0.288)	(0.290)
Observations	17,881	17,881	18,193	18,193
R-squared	0.082	0.081		

Notes: Dependent variable is a child’s height-for-age Z-scores calculated from DHS datasets.

In columns 2 and 4, well water was substituted for piped water and borehole water to test for robustness.

Robust standard errors are in parentheses.

***P<0.01, **P<0.05, *P<0.1 indicates coefficient significance at 1%, 5%, and 10% levels, respectively.

The marginal effect also indicates that the probability of a boy being stunted is about 0.13 higher than that of a girl. The heights of children with siblings (multiple births) are likely to be 0.18 Z-scores less than single births (only children). The probability of being stunted for a child with siblings is about 0.12 higher than that of only children. This result is consistent with the theory that children with siblings are generally more disadvantaged than only children, due to insufficient breast feeding. The coefficient of a child’s birth order suggests that a child’s height is likely to be 0.07 Z-scores less as the birth order of a child increases (Sahn and Stifel 2002b;

2003a; Kabubo-Mariara et al. 2008). The probability of a child being stunted rises by 0.05 the further down the birth order a child is.

We now turn to the effects of environmental variables on children's height-for-age Z-scores. Access to piped water and borehole water are both positive and significant determinants of children's heights. The effect of borehole water is stronger than that of piped water.

While access to borehole water is significant at the 1 percent statistical level, piped water is only significantly related to children's height at the 5 percent level. The height of a child that has access to piped water is likely to be 0.14 Z-scores higher than a child with access to well water. In line with this finding, the probability of being stunted is about 0.07 lower for a child with access to piped water than for a child with access to well water. Similarly, the height of a child drinking borehole water is likely to be 0.26 Z-scores higher than a child drinking water from a well. For a child that has access to borehole water, the probability of being stunted is about 0.16 Z-scores lower than for a child that has access to well water.

We substituted well water for piped water and borehole water in columns 2 and 4 to check for the robustness of the effects of safe drinking water on a child's height-for-age Z-score. The result suggests that a child's height Z-score is likely to be lower by 0.22 Z-scores for a child that drinks well water and the probability of being stunted is about 0.14 higher. This confirms the negative effects of well water on children's health in Nigeria and that provision of safe drinking water should be one of the main priorities of the government.

Regarding sanitation, access to pit latrines and flush toilets are both positive determinants of children's heights and are inversely related to the probability of being stunted. However, improved waste disposal, households' access to flush toilets, is a significant and positive determinant of children's height-for-age Z-scores. Flush toilets are statistically significant at the 1 percent level. The height Z-score of a child with access to a flush toilet will be about 0.56 higher than a child with no access to a flush toilet. The probability of being stunted is about 0.3 Z-scores lower for children with access to flush toilets than children with no access to flush toilets. This finding strongly supports the argument that safe disposal of human waste is essential for the healthy life and adequate growth of children. Our result agrees with Silva (2005), but contradicts Kabubo-Mariara et al. (2008).

The height of a child's mother is a positive and significant determinant of a child's height-for-age Z-score, but is inversely related to the probability of being stunted. The height of the mother captures genetic effects and other family background characteristics (Kabubo-Mariara et al. 2008). As expected, the relationship between wealth and child height Z-scores confirms that wealthier households can take better care of pregnant women and feed the children, compared to poor families. This result supports the findings of Haddad et al. (2003). Household size is negative and significantly related to the height of children. This is also not surprising since the cost of living for large households is generally higher compared to smaller households. Nonetheless, this finding further emphasizes the importance of family planning for the sake of prioritizing nutrition for children.

We found that the age of the mother is positive and statistically significant (at the 1 percent level) in relationship to children's height-for-age Z-scores. Also, the probability of a child being stunted is lower by 0.02 for older mothers, compared to younger mothers, implying that children born to teenagers are more likely to be undernourished than children born to adult mothers. Mothers' years of education is both positive and significant in determining the nutritional status of children. When mothers are educated, they have better information on children's health care and generally earn higher incomes than mothers who are not educated. The probability of a child being stunted is about 0.12 lower when a child's mother is educated than when she is not educated. This is one of the reasons why investment in human capital, especially that of women, has great importance, given the pivotal role that women play in the upbringing of children.

In table 2, we present the results of the effects of households' access to safe drinking water and sanitation on children's weight-for-age Z-scores. The results here echo the findings on height z-scores above. The age of a child in months, being male, multiple births (siblings), and birth order, all have negative effects on the weight of children. These four variables are negative and statistically significant determinants of children's weight Z-scores and their probability of being underweight has a 1 percent level of significance. As earlier explained with height Z-scores, weaning and insufficiency of breast feeding as a child's age increases in months explains the negative effects of age in months on children's weight.

The male dummy variable indicates that boys are 0.11 lower in weight-for-age Z-scores than girls. The probability of being underweight is also higher by 0.11 for boys than for girls. Children with siblings (multiple births) are 0.17 weight Z-scores below only children (single births) and their probability of being underweight is about 0.14 higher. The probability of a child being underweight is also an increasing function of a child's birth order. Neither of these results is surprising, since children with more older siblings have to compete for nutrition from the mother. Our result is consistent with previous studies on children's weight (Kabubo-Mariara et al. 2008; Khanna 2008; Silva 2005; and Skoufias 1998).

Table 2. Effects of Sources of Drinking Water and Sanitation on Children's Weight

Independent variables	*Column 1* Weight Z-score	*Column 2* Weight Z-score (well water)	*Column 3* Probit marginal effects	*Column 4* Probit marginal effects (well water)
Age in months	-0.0123***	-0.0123***	0.00275***	0.00275***
	(0.000807)	(0.000808)	(0.000754)	(0.000754)
Male dummy	-0.110***	-0.110***	0.114***	0.114***
	(0.0241)	(0.0241)	(0.0231)	(0.0230)
Multiple births	-0.170***	-0.170***	0.139***	0.139***
	(0.0538)	(0.0537)	(0.0498)	(0.0499)
Birth order	-0.0569***	-0.0570***	0.0581***	0.0581***
	(0.00959)	(0.00958)	(0.00892)	(0.00892)
Piped water	**0.0363**		**-0.0517**	
	(0.0507)		**(0.0446)**	
Borehole water	**0.0737***		**-0.0801****	
	(0.0404)		**(0.0401)**	
Pit latrine	**-0.0322**	**-0.0321**	**0.0318**	**0.0319**
	(0.0398)	**(0.0398)**	**(0.0360)**	**(0.0361)**
Flush toilet	**0.416*****	**0.414*****	**-0.269*****	**-0.266*****
	(0.0551)	**(0.0554)**	**(0.0572)**	**(0.0574)**
Mother's weight	0.000724***	0.000722***	-0.000290	-0.000289
	(0.000212)	(0.000212)	(0.000180)	(0.000180)
Wealth index	0.00334	0.00339	-0.00130	-0.00131
	(0.00735)	(0.00734)	(0.00650)	(0.00649)
Household size	-0.0131***	-0.0131***	0.0112***	0.0112***
	(0.00490)	(0.00490)	(0.00409)	(0.00409)
Mother's age	0.0256***	0.0257***	-0.0246***	-0.0247***
	(0.00300)	(0.00300)	(0.00323)	(0.00323)
Parent education	0.106***	0.106***	-0.191***	-0.190***
	(0.0120)	(0.0121)	(0.0223)	(0.0223)
Well water		**-0.0622***		**0.0718****
		(0.0366)		**(0.0353)**
Constant	-1.117***	-1.055***	-0.387***	-0.459***
	(0.0759)	(0.0813)	(0.0794)	(0.0848)
Observations	18,033	18,033	18,347	18,347
R-squared	0.067	0.067		

Notes: Dependent variable is a child's weight-for-age Z-score and probability of being underweight calculated from DHS datasets.

In columns 2 and 4, well water was substituted for piped water and borehole water to test for robustness.

Robust standard errors are in parentheses.

***P<0.01, **P<0.05, *P<0.1 indicates coefficient significance at 1%, 5%, and 10% levels, respectively.

Households with access to piped or borehole water and flush toilets are all positively related to children's weight-for-age Z-scores. While access to borehole water is significant at 10 percent, access to a flush toilet is significant at the 1 percent level of significance. Access to piped water is a positive but weak determinant of a child's weight Z-score. Such children have about 0.07 Z-scores greater than children with access to well water. The probability of being stunted is about 0.08 lower for children with access to borehole water, compared to those that drink well water. Our results in tables 1 and 2 show that access to borehole water is more relevant to children's heights and weights in Nigeria than piped water. This is partly due to the quality of piped water, which in most cases is not sufficiently treated by state water corporations. Borehole water is generally not treated in Nigeria because of the public belief that it is clean.

The significance of improved sanitation on children's health is reflected by the coefficient for flush toilets. Access to flush toilets is positive and statistically significant at the 1 percent level in relationship to a child's weight-for-age Z-score. The probability of a child being underweight is also inversely related to access to a flush toilet. The probability of being underweight for children with access to flush toilets is 0.27 lower than for children with no access to flush toilets. Pit latrines are negatively related to children's weight Z-scores. Most pit latrines are open and are not always treated. It is clearly necessary to encourage households to invest in flush toilets to prevent outbreaks of disease and improve children's heath, especially given children's low immunity.

The weight of the mother is a positive and significant determinant of a child's weight-for-age Z-scores. The variable is significant at the 1 percent level of significance. Wealth is positive, but is not a significant determinant of children's weight. As with height, household size is both a negative and significant determinant of children's weight. The weight-for-age Z-scores of children in large households is about 0.013 lower than for children in relatively smaller households. Similarly, the probability of being underweight is about 0.011 higher in large families than in small families. The years of education of a child's mother is also a positive and significant determinant of children's weight Z-score, being about 0.11 higher if the mother is educated than if the mother is not. The probability of a child being underweight is about 0.19 lower when the mother is educated than when the mother is not educated.

Last, a child who drinks water from a well has about 0.06 weight-for-age Z-scores less than a child that gets water from a borehole. The probability of children being underweight is about 0.07 higher when children drink well water, compared to piped and borehole water.

7. Conclusion and Policy Implications

Looking at the implications of households' access to safe drinking water and sanitation on children's health outcomes in this study, our results show that households' access to piped and borehole water are both positively related to children height- and weight-for-age Z-scores. Importantly, we find that borehole water is more significant and positively related than piped water in Nigeria. We argue that the quality of piped water needs to be critically assessed to determine the main reason for the weak relationship it has to children's health outcomes. We suspect that the quality and quantity of water treatment chemicals applied to piped water before it is distributed to the public may be at issue. In the short term, however, policymakers should consider funding more boreholes throughout Nigeria for household use and at the same time improve the quality of piped water for the health of millions of children in the country.

In line with our findings, access to proper disposal of human waste, especially flush toilets, is crucial for the healthy growth of children. Children in households with access to flush toilets are less prone to chronic malnutrition (inadequate growth). Our study also shows that access to flush toilets reduces the probability of a child becoming stunted. The Nigerian government should clearly invest in the provision of flush toilets for households to reduce the occurrence of cholera and other water-borne diseases that presently ravage the country. Our results also show that pit latrines are not significantly related to children's health, but are positively related to children's probability of being underweight.

Our study shows that drinking well water is harmful to the growth of children in Nigeria and has positively increased the number of children being stunted and underweight. It is a strong signal to the various tiers of government to expedite efforts to provide safe drinking water to every household in the country. Women's education is another area that clearly should be promoted and encouraged by the government because of its positive impacts on the health outcomes of children.

If Nigeria and the other national governments of sub-Saharan Africa can improve drinking water and sanitation, the lives of millions of children will be saved. Providing safe drinking water and better sanitation will also increase both the physical and mental growth of children. Multiplier effects of adequate access to safe drinking water and sanitation include a healthier environment, reduction in public expenditure for water-borne diseases, and greater economic growth due to the positive effects of a vibrant and healthy population.

Finally, we recommend further studies on the quality of piped water in Nigeria and how to reduce the average cost of borehole drilling, in addition to finding solutions to the persistence of water borne diseases.

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