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The Impact of Drinking Water Quality and Sanitation on Child Health: Evidence from Rural Ethiopia

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Abstract

This paper examines the impact of drinking water quality and sanitation behavior on child health in rural districts of Ethiopia. Using primary household survey data and microbiological water test for *Escherichia coli*, we use various estimation methods to quantify the impacts of water quality and sanitation behavior on diarrhea incidence among children under five years old. Our results show that uncontaminated household storage water and safe child stool disposal decrease incidence of child diarrhea by 16% and 23% respectively. In contrast, neighborhood concentration of pit latrine increases incidence of child diarrhea by 12%. The latter result casts serious doubt on the assumed health and social benefits of moving from open to fixed-location defecation. Creating open defecation free communities in rural areas is not enough to achieve the desired health benefits of sanitation. To protect rural households from the risk of contracting communicable diseases, existing pit latrines should be upgraded to make them safer to use – fly-proofed and hygienic. There is a need for appropriate policy actions to improve household drinking water quality and to change people’s behavior towards safe sanitation practices. Increasing access to clean water supply and providing means for safe excreta disposal will bring significant health and social gains. Moreover, promotion of hygiene education campaigns about household water treatment, safe water storage and handling, washing hands with soaps at critical times, and adequately removing child feces from the domestic environment can also help ensure that people preserve good health in their household and their community.

Keywords: drinking water quality; sanitation; hygiene; child health; diarrhea; instrumental variable; rural Ethiopia.

JEL classification: I1, D1, C36, Q53

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1 Introduction

Globally, more than 700 million people live without an improved water source,[1] and eight out of ten of these people live in rural areas. An estimated 2.5 billion people − over one-third of the world population − lack access to improved sanitation facilities, and of which a billion people practice open defecation (WHO/UNICEF 2014). Sub-Saharan Africa, and Southern and Eastern Asia are the regions with the lowest coverage of improved sanitation in the world. In parallel, millions of people are suffering worldwide from diseases related to water, sanitation and hygiene (WASH), such as diarrhea, skin diseases and trachoma. Unsafe water, inadequate sanitation and poor hygiene are linked to 88% of diarrhea cases worldwide and result in more than 1.5 million children deaths each year – mostly among children under the age of five (WHO 2002; WHO/UNICEF 2009).

Ethiopia is the second-most populous country in Africa and about 85% of the country's 96 million people lives in rural areas.[2] Mortality and malnutrition are serious health problems among under-five children in the country. Although the country has reduced under-five mortality rate by more than half since 1990 (UNICEF 2012), Ethiopia was ranked 27th in the global under-five child mortality rate estimates in 2007 (UNICEF 2009). According to the World Bank (2005) Country Status Report on Health and Poverty, child mortality in Ethiopia is among the highest in the world; nearly one in every ten babies born in Ethiopia (97 per 1000) do not survive to celebrate their first birthday, and one in every six children die before their fifth birthday. The FMoH (2010) report indicated that the national under-five child mortality rate was 123 per 1000 live births, and 90% of the deaths were due to preventable diseases such as pneumonia, diarrhea, malaria, measles, malnutrition and HIV/AIDS.

The spread of diseases caused by poor water supply and sanitation services is a major health problem in Ethiopia. The Ethiopian Federal Ministry of Health (FMoH) (2005) estimated that 60% of the country's disease burden and 70% of the diarrheal diseases were mainly attributed to poor WASH. Furthermore, poor WASH is a substantial problem in both rural as well as urban areas of the country (WHO/UNICEF 2012). It is commonly believed that most of the deadly diseases caused by poor WASH are largely preventable.

To achieve the Millennium Development Goals (MDGs), the Government of Ethiopia (GoE) has made significant progress in increasing access to water and sanitation service, and in modifying long-held hygiene habits. Nonetheless, as shown in Figure 1, access to proper sanitation facility is inadequate – particularly in rural areas. There is also a striking difference between urban and rural households: based on the WHO definition, only 28% of rural

[1] WHO/UNICEF Joint Monitoring Programme (JMP) for water supply and sanitation defines an improved drinking water sources as one that is adequately protected from outside contamination, in particular from the contamination with faecal matter, and an improved sanitation facility is defined as one that hygienically separates human excreta from human contacts.

[2] http://worldpopulationreview.com/countries/ethiopia-population/

households have access to improved sanitation while the remaining households rely on unsafe sanitation services and open defecation. This issue is compounded by water source contamination by animal and human feces, which is caused by inadequate protection to most water sources in rural areas. WHO/UNICEF (2015) estimated that 57% of Ethiopian households have access to improved drinking water sources – 93% in urban areas and 49% in rural areas. As a result, most of the rural population rely on unimproved water sources, such as rivers, lakes, ponds, streams, rainwater, unprotected springs and wells, irrigation water from canals and dams, as a source of water for drinking and other domestic uses. Moreover, less than 20% of the population are regularly washing their hands with soap and water at critical times (FMoH 2011). The same report indicated that only 8% of the population follow the safe drinking water chain from source to mouth (FMoH 2011). Due to unsafe handling and storage of drinking water, 40% of the domestic water consumption is contaminated with fecal matters.

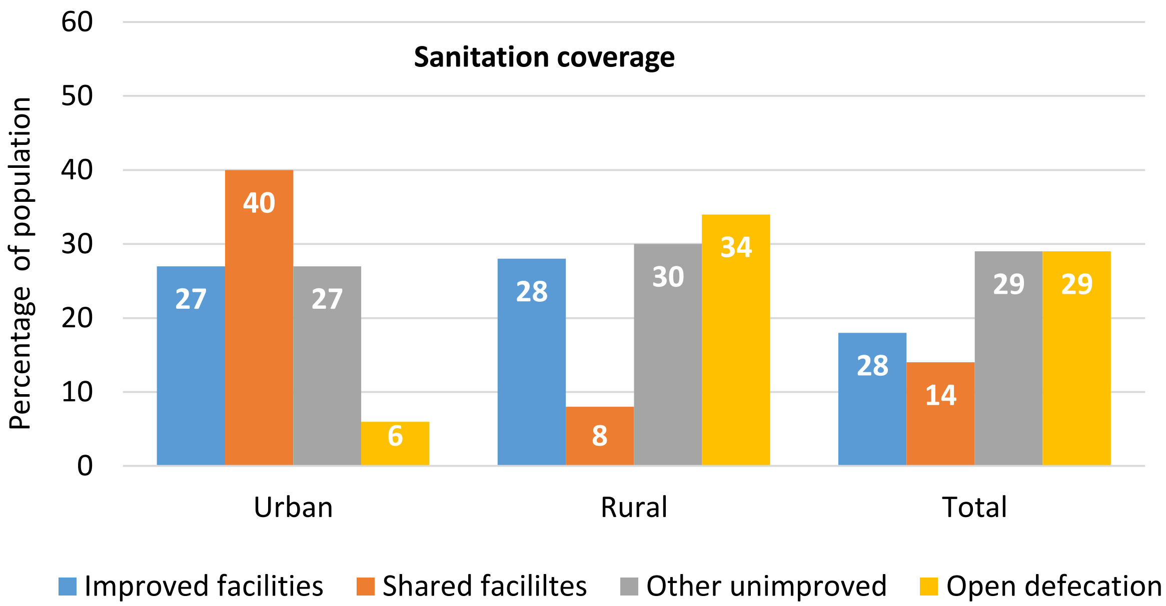

Figure 1: Percentage of population by type of sanitation facility in Ethiopia, 2015

Source: Authors' compilation using the WHO/UNICEF Joint Monitoring Programme (JMP) dataset

The impacts of unsafe drinking water and sanitation behavior on child health outcomes have not been investigated sufficiently, and very little is known about the impacts in the context of rural Ethiopia. Existing empirical works on the health impacts of water and sanitation in Ethiopia did not give due attention to water quality at the household level and child stool disposal habits (Cameron 2009; Kirchberger 2008).

Using a variety of impact evaluation methods, this paper aims to shed more light on the health impacts of household drinking water quality and sanitation behavior on children under five years old in two rural areas in Ethiopia – Fogera and Mecha districts. The innovative aspects of this paper lies in two key contributions: first, household's drinking water quality was determined by actually testing the microbiological quality of water samples taken from drinking water stored in the household,[3] using a membrane filtration method rather than looking at the types of household drinking water sources. A second novelty of this paper is that, we take into account household's behavior on child stool disposal which plays an important role in child health outcomes. The key findings are that improved storage water quality and safe child stool disposal highly influence childhood diarrhea. However, contrary to widely held perceptions, the results suggest that we should think differently about the health impacts of simple pit latrines in rural areas.

The remainder of the paper is structured as follows: The next section reviews the literatures related to our study. Section 3 presents the data, including some statistics, and a discussion of testable relationships between the data. Section 4 outlines our empirical strategy. Section 5 presents the estimation results and discussion. The last Section presents the summary and conclusion of this study.

[3] Hereafter referred to as storage water

2 Water Supply, Sanitation, Hygiene and Health – Literature Review and Conceptual Framework

Improving WASH services has been recognized as a fundamental factor to improve health and as one of the driving forces of social and economic progress in developing countries. Improving water quality and sanitation, together with better hygiene practices, can have significant effects on the health of a population. It reduces the incidence of a variety of waterborne diseases, such as diarrhea, intestinal helminthes, guinea worm, skin diseases, and trachoma (Esrey *et al.* 1991), by interrupting or reducing the transmission of pathogenic disease agents. These health improvements can in turn lead to improved nutritional status and reduced morbidity and mortality, particularly among under-five children. Table 1 presents potential transmission routes of pathogens and a broader classification of disease burden associated with unsafe and inadequate water supply.

Table 1: Transmission Routes of Water-Related Diseases

Classification	*Transmission route*	*Examples of diseases transmitted*
Waterborne	through ingestion of pathogens in drinking water	Diarrheal diseases Enteric fevers, such as typhoid Hepatitis A
Water-washed	through incidental ingestion of pathogens in the course of other activities; results from having insufficient water for bathing and hygiene	Diarrheal diseases Trachoma Scabies
Water-based	through an aquatic invertebrate host; results from repeated physical contact with contaminated water	Guinea worm Schistosomiasis
Water-related insect vector	through an insect vector that breeds in or near water	Malaria (parasite) and Yellow fever (virus)

Source: Bradley (1977).

Diarrhea is both a waterborne as well as a water-washed disease, and it can be caused by ingesting water contaminated with human and animal feces which contain pathogenic agents or ingesting these pathogens directly through various fecal-oral pathways. The latter is likely to occur when water availability is limited, which hinders proper hygiene practices (e.g., washing hands after defecation). Although diarrhea and malaria are the most prevalent diseases in the study areas, this paper focuses on diarrhea in under-five children.

Figure 1 shows the fecal-oral routes of disease transmission and how intervention can break the chain of contamination at various stages of the transmission pathways. Human and animal excreta are the primary sources of most disease-causing pathogens. As the figure illustrates, these pathogens are passed from an infected host to a new one via various transmission routes. They are transmitted via the fecal-oral routes through fluids, hand contact, flies and food. The figure also shows the importance of sanitation and safe removal of human feces as a primary barrier to prevent these pathogens from reaching the domestic environment. Good hygiene practices and household water treatment also serve as a secondary barrier to prevent the transmission of diseases-causing pathogens. For example, washing hands with soap after defecation and contact with child stools, and before eating and preparing food stop the transmission of disease agents because the source of the diarrhea pathogen is removed. Therefore, washing hands with soap can significantly reduce the burden of diseases associated with feces and polluted water. The secondary barriers are extremely important when sanitation services are inadequate and feces are disposed of into the domestic environment.

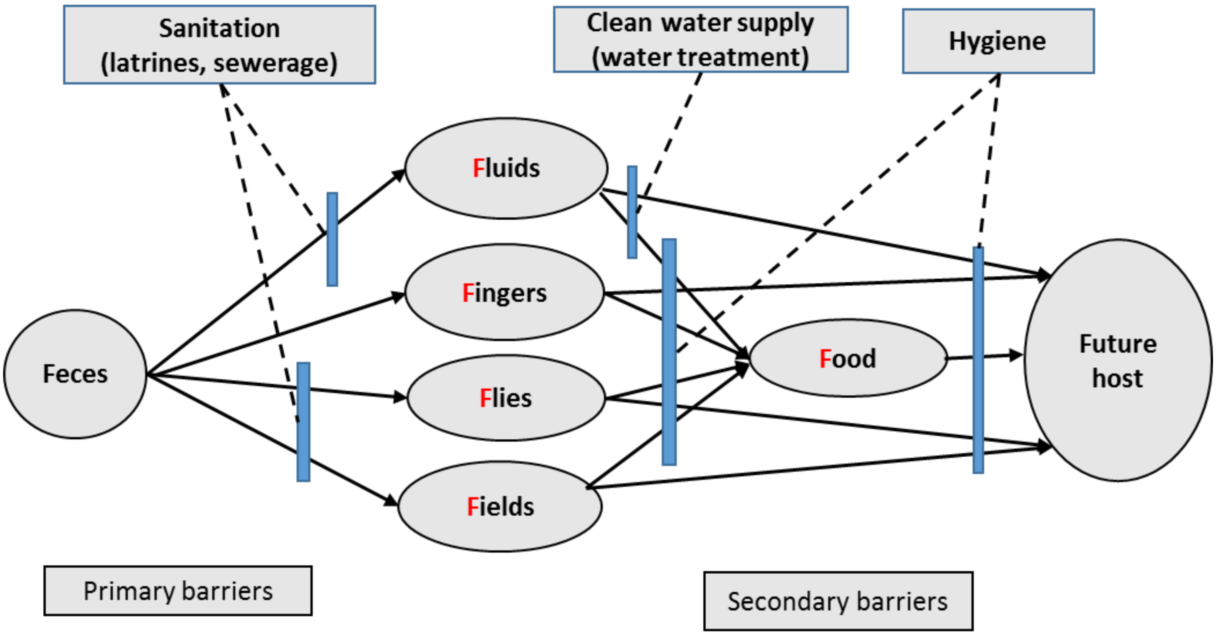

Figure 2: The "F-diagram" shows the pathways of fecal disease transmission and the barriers that can prevent infection

Source: adapted from Wagner and Lanoix (1959).

2.1 Water Supply and Health

Water is an essential resource needed to sustain life on earth. Numerous empirical studies have investigated the impact of water supply and sanitation infrastructure on human health. There is compelling empirical evidence that access to improved drinking water supply substantially improves child health in terms of reducing the risk of diarrheal diseases (Esrey *et al.* 1990; Fewtrell *et al.* 2005; Overbey 2008). Safe, reliable, and easily accessed water is crucial for the preservation of good health. However, in many developing countries – particularly in rural areas – the available water is often either unsafe or insufficient to meet basic health needs. The United Nations General Assembly declared "safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights" and openly called for actions leading to the provision of "safe, clean, accessible and affordable drinking water and sanitation for all" (United Nations (UN) 2010).

The quantity of water available to a given household is largely affected by traveling and waiting time taken to collect water (Cairncross 1987). After reviewing several studies, Cairncross (1987) found the following general relationship between water use and collection time: a) the quantity of water collected decreases considerably once the time taken to collect water is greater than 5 minutes (water source is located 100 m away from home); b) the quantity of water remains the same between 5 and 30 minutes of collection time (distance travelled lies between 100 m and 1000 m); and c) the quantity of water decreases further when the nearest water source is 1000 m away from home (total collection time longer than 30 minutes). The findings of an empirical study in Uganda provided evidence to support to this observed relationship (WELL 1998). Reducing water collection time directly increases water availability, and this may translate into more bathing and washing (Cairncross & Cuff 1987). In particular, the frequency of handwashing is highly correlated with the quantity of water available to households (Cairncross 1997; Curtis *et al.* 2000; Gilman *et al.* 1993). To minimize the health risk associated with poor hygiene, 50 liters of water per capita per day (l/c/d) is recommended to ensure adequate personal and food hygiene, domestic cleaning, and laundry needs (WHO 2011); 7.5 liters or water is the recommended absolute minimum for consumption and cooking in emergencies and disasters (Howard & Bartram 2003). In rural Ethiopia, the average domestic water consumption is probably much lower than the recommended amounts, with the estimated amount of drinking water for urban and rural population varying between 3 and 20 l/c/d (Kumie & Ali 2005). This is mainly due to the long distances between households and their nearest water source, which requires a considerable amount of time and energy to collect water.

Water Access and Collection Time

In sub-Saharan Africa, it is estimated that 40 billion working hours are lost each year as a result of collecting water (Blackden & Wodon 2006). It is also well-documented that it is mostly women and girls who have to travel long distances and spend their productive time on fetching water (WHO/UNICEF 2010b). For example, in Malawi, 87% of water fetching duties are taken up by women and 20% of the households spend more than an hour for each water collection trip (Sorenson *et al.* 2011). In rural Ethiopia, adult women are 10 times more likely to collect water for household consumption than adult men and 63% of the households need to travel 30 minutes or more for each water collection trip (CSA and ICF International 2012). Consequently, it is often argued that the time spent collecting water by women and girls could be used for other income-generating activities, such as seeking access to health care, schooling, leisure, participating in community activities and taking care of young children (Ray 2007; Sorenson et al. 2011), with direct and indirect health consequences.

Water quality is also an essential aspect of access to improved water supply. Unsafe drinking water is not only dirty, but it can be also pathogenic and deadly if people consume it untreated. More than 1.6 million children die each year due to diarrheal and other gastrointestinal diseases, mostly in developing countries, and contaminated drinking water is considered to be one of the major causes (Kremer & Zwane 2007; WHO/UNICEF 2009). Unsafe drinking water may also result in other waterborne diseases such as typhoid, cholera, and dysentery. There is extensive empirical support for the critical role of safe water supply in improving and preserving good human health, in both rural and urban areas. Most of the existing literature focuses on the impacts of households having access to piped water connection, and children have been shown to benefit substantially from improved water sources (Bukenya & Nwokolo 1991; Mangyo 2008). Moreover, the health benefit of in-house water connection is substantially greater than that of improved public sources, such as standpipe and other protected water sources (Bartram & Cairncross 2010; Curtis *et al.* 1995).

2.2 Sanitation and Health

Improved sanitation facility, together with safe water and proper personal hygiene, is fundamental to good health. According to the World Health Organization, “no single type of intervention has greater overall impact upon national development and public health than the provision of safe drinking water and the proper disposal of human excreta” (WHO 1996). Lack of adequate sanitation facility can cause diarrheal and other diseases which can be transmitted via the fecal-oral route. Access to safe and adequate drinking water alone is not enough to decrease the disease burden because improved sanitation is also a crucial component of the WASH sector. Improved sanitation technology (e.g., toilet and sewerage systems) creates the primary barriers to prevent fecal pathogens from reaching the environment and can reduce a number of health risk factors.

Kumar and Vollmer (2013) analyzed nationally representative data (District Level Household Survey, DLHS-3) for India and found a 2.2 percentage point reduction in diarrhea incidence in under-five children living in households with improved sanitation facilities. A similar study in Nepal by Bose (2009) showed an even larger reduction (11%) among younger children (below 24 months old).

The child stool disposal behavior of households is also an important factor in the prevention of diarrheal diseases. If children’s feces are not contained or safely disposed of away from the living area, young children might be exposed to the stools through direct contact, which can cause diarrhea via the hand-to-mouth pathway. Haggerty et al. (1994) found that promoting handwashing and safe disposal of human and animal excreta from domestic environment results in an 11% reduction in diarrhea morbidity in rural Zaire.

2.3 Hygiene Behavior and Health

Promoting good hygiene behavior is crucial for realizing the full benefit of improved water supply and sanitation facilities. While water and sanitation infrastructure interventions are often considered as the 'hardware' of WASH, the promotion of behavior change is usually considered as the 'software' of such interventions. Hygiene is a set of practice or change of behavior that people adopt to preserve their health. However, changing hygiene behavior is a complex process as it requires people to change their long-held habits, which have been influenced by cultural and socio-economic factors. Although educating people to change their behavior is a complex and uncertain task, Curtis et al. (2000) suggested that hygiene interventions can be successful if a few behaviors that have most potential health impacts are targeted and promoted. For instance, promoting handwashing intervention, and safe water storage and handling practices can produce significant health gains.

Hands are an important vector in the transfer of pathogens from feces as hands can become contaminated through various mechanisms: during defecation, while disposing of child stool, or by touching other contaminated objects (Hill et al. 2004). However, there is a growing body of evidence that simply washing hands with water and soap at critical times – such as after stool disposal or defecation, and before preparing food or eating – can help a person avoid life-threatening water-related diseases. Moreover, existing literature has suggested that promoting handwashing has shown the most success in achieving greater health impact. Curtis and Cairncross (2003) suggested that handwashing with soap could reduce diarrhea incidence by 47% and save at least one million lives per year. This is consistent with other studies which found that handwashing interventions achieved a median reduction in diarrhea incidence by 35% (Hill et al. 2004). In a randomized controlled trial in urban Pakistan, Luby et al. (2006) found that intensive handwashing promotion could reduce diarrhea incidence by 51%. Luby et al. (2005) also analyzed the effect of handwashing with soap on the incidence of pneumonia and diarrheal diseases and found strong supporting evidence: in households that received the intervention, diarrhea incidence reduced by 53%, and pneumonia incidence by 50% in under-five children. A recent review of hygiene practices by Cairncross et al. (2010) also indicated that handwashing with soap can result in a 48% diarrhea risk reduction in low- and middle-income countries where there is access to water.

There is also a wealth of evidence indicating that point-of-use (POU) water treatment, and safe water storage and handling lower the risk of exposure to waterborne pathogens, in turn reducing child diarrhea incidence. A systematic review suggested that treating water with chlorine tablet at the point of use reduces not only the risk of Escherichia coli (E coli) contaminating storage water but also the risk of child diarrhea significantly in developing countries (Arnold & Colford 2007). There is a very limited number of empirical studies that have investigated the impact of improved water transport and storage containers on health outcomes. However, a recent study examining the impact of improved water transport and storage on water quality and health outcomes in Benin by using a randomized control trial approach found that improved water storage and containers are associated with both a reduction in *E. coli* colony count in water and a lower incidence of self-reported diarrheal diseases (Günther & Schipper 2013).

Improving the quality of drinking water at household level can bring additional health improvements. Drinking water collected from improved sources may be contaminated because of poor water storage and unhygienic water handling before reaching the drinking cup. For instance, a systematic meta-analysis of 33 studies conducted by Clasen et al. (2007) showed that water treatment at the point of use using flocculation or disinfection is more effective in reducing risk of diarrhea than water source improvements.

Generally, existing empirical studies suggest that a number of WASH interventions are effective in reducing water- and fecal-related disease burden. However, the empirical evidence regarding whether multiple interventions are more effective than single intervention is mixed. A number of studies have shown that using various combinations of interventions are more effective than using one alone (ALAM et al. 1989; Esrey et al. 1991; van Der Hoek et al. 2001). On the other hand, a comprehensive meta-analysis by Fewtrell et al. (2005) found that combining interventions did not have any synergistic effect, which is contrary to the above discussion and the wider beliefs. Finally, Table 2 presents the summary of a meta-analysis of the percentage reduction in diarrheal diseases by intervention type. Waddington et al. (2009) found that water supply interventions did not bring statistically significant reduction in diarrheal morbidity but water quality interventions generated greater diarrheal morbidity reduction. On the other hand, Fewtrell et al. (2005) and Esrey et al. (1991) respectively found hygiene and sanitation interventions had greater impacts.

Table 2: A meta-analysis of percentage change in diarrheal diseases by intervention type

	Esrey *et.al.* (1991)	**Fewtrell *et.al.* (2005)**	**Waddington *et.al.* (2009)**
Water quality	-15%	-31%	-42%
Water supply	-20%	-25%	-2%*
Sanitation	-36%	-32%	-37%
Hygiene	-33%	-45%	-31%

*Not significant

3 Data and Methods

The data used in this paper were taken from a primary household survey conducted in two districts of rural Ethiopia between February and June 2014. This study was carried out in the Fogera and Mecha districts of the Amhara National Regional State (ANRS) in Northwest Ethiopia. It covers 454 households across 20 kebeles with 565 children aged five or younger. The data comprises household- and community-level data with microbiological water sample test results.

3.1 Data Collection and Household Sample

The sample households were selected using a stratified two-stage cluster sample design, whereby villages were taken to be the primary sampling units (PSUs) and agricultural households were considered to be the secondary sampling units (SSUs). The first-stage sample selection of villages/clusters was random but proportional to size (PPS). Subsequently, the second-stage sample units (SSUs), agricultural households, were selected within each village based on the systematic random sampling (SRS) method. The geographical and the lowest administrative division of the region (i.e., kebele) is used to form the first level of stratification. In the first stage of the sample selection process, 61 clusters or villages were randomly selected from 20 administrative kebeles. This was followed by a systematic random sample selection of 454 agricultural households from a complete listings of agricultural households — covering the entire target population.[4] The household head lists were provided by the Woreda's Agriculture and Extension Bureau. One of the selection criterion for a household was having at least one child under-five years. As such data was not available beforehand — during the first stage selection process; households without under-five child were replaced by the nearest neighbor households during the field work.

We used structured questionnaires to collect a range of information.[5] We collected data on characteristics of housing, water supply sources, continuity of water supply and seasonal change, water treatment and storage, toilet facility, solid waste management, hygiene behavior and knowledge, agriculture production, consumption, expenditure, and household member's labor use and health status. Other detailed information, such as nutritional and health status about under-five children of selected households, were also collected. In most cases, the respondents were the primary caretakers concerning household consumption, water and sanitation and child health. In compliance with ethical considerations, households were also consulted about their willingness to participate in the study.

[4] A household is a group of people who live together and take food from the same plate, and someone who has lived in the household at least six months.

[5] In addition to the English language, the questionnaires were translated into Amharic — the mother tongue of the study areas.

3.2 Microbiological Water Quality Tests

There are several physiological, chemical and microbiological standards for a water source to be acceptable for human consumption. One of the most commonly used indicator for microbial water quality is the level of *E. coli* bacteria[6], which only comes from human and animal feces. It is almost impossible to reliably predict the microbial quality of water at the household's storage unit based on the type of the water source as water collected from improved sources is often re-contaminated by fecal matters during collection and transportation due to poor water handling and storage (Wright *et al.* 2004). Therefore, in this analysis, the level of *E. coli* bacteria colony coliform unit per 100 ml of storage water (cfu/100 ml) was used as the indicator of the microbial drinking water quality.[7]

Water samples were collected from the stored water in each selected household, then the collected water samples immediately were placed into the portable test kit on-site and incubated for a maximum of 24 hours at the temperature of 44 degree Celsius.[8] The bacteria colonies grew on the Membrane Lauryl Sulfate Broth (MLSB) medium, which is specifically formulated to facilitate the growth of *E. coli* bacteria and prevent the growth of other micro-organism. Because bacteria are very small, they should be grown on nutrient plates so that they can multiply rapidly and, depending on the test kit, become visible within 24 hours. *E. coli* concentrations are reported as colony forming units per 100 ml of water sample.

3.3 Variables and Measurement

Dependent variable

In this paper, we use diarrheal diseases as a health indicator and focused on child health outcomes.[9] According to the World Health Organization (WHO), diarrhea is generally

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[6] We could not test all known pathogens that can pose a health risk because it is both complicated and expensive. For instance, streptococci and thermotolerant are used as an indicator of drinking water quality as they have a close relationship to bacteria indicators of known fecal origin.

[7] The general WHO Drinking Water Quality Guideline suggests that the number of *E. coli* coliform colony counts per 100 ml water should be zero when used as an indicator of microbiological drinking water quality.

[8] Immediately after the water samples were collected from the household storage, we prepared the growth pads by dispensing the growth medium into a sterile Petri dish and a dissolved media solution was poured over the growth pad. Then the water sample was filtered through the membrane; when all the 100 ml water has been filtered, we placed the membrane on top of the pad, which has been saturated with the MLSB media. In the next stage, we replaced the Petri dish lid and labelled it with its sample identification number and the time of collection. Then we placed the Petri dish on a Petri dish rack. Finally, we placed the filled rack into an incubator and let the samples incubate for between 20 to 24 hours at the temperature of 44 degree Celsius. Upon completion of the incubation period, we enumerated the number of *E. coli* colony coliform units per 100 ml. In this method, accurate enumeration of bacteria colony is difficult when the coliform bacteria counts are greater than 200 cfu/100 ml water.

[9] Although poor water quality can cause other communicable diseases and can also affect adults, we focused on child diarrheal diseases as the health indicator in this analysis. Young children and infants are more prone to diarrheal diseases than adults due to their weak immune system. Moreover, diarrhea is one of the leading

defined as the passage of three or more "loose watery stools" in a twenty-four hours period. Data on the incidence of diarrheal diseases in the two weeks preceding the survey were collected. In most of the cases, the respondents are the child's primary caretaker – usually their mother.

Control variables

Based on existing empirical literatures, a set of household and child characteristics, water collection time, latrine characteristics, child stool disposal, and handwashing practices are included in the analysis to control for observed differences among households. The study therefore makes the hypothesis discussed below regarding the independent effects of explanatory variables on childhood diarrhea. The description of variables and units of measurement are summarized in Table 3.

Socioeconomic variables

We start here by considering the "traditional" variables. The ages of both parents and children are expected to have a negative impact on childhood diarrhea incidence. Younger mothers may lack the necessary experience to provide better care for their children. Due to their weak immune systems, infants and young children are susceptible to diarrheal diseases; however, they become more resistant to the diseases as they grow older. The level of household awareness of the health benefits of water quality, safe sanitation and good hygiene practices highly depends on the level of education among household members and is expected to affect child health positively (i.e., decrease diarrhea incidence). As the level of education for both household head and primary caretaker were very low, the highest grade completed among the household members was used as a proxy for education.

Moreover, in developing countries, socioeconomic factors, such as wealth, also influence the type of drinking water source used by households (Braind *et al.* 2010; Larson *et al.* 2006) and are expected to be negatively associated with incidence of child diarrhea. To control for wealth and other unobserved health practices, household asset was used as a proxy for wealth.

A household's demographic structure may play a role in determining health outcomes. Household density, dependency ratio, and the number of young children are expected to be positively associated with child diarrhea incidence. In rural areas, housing structures are poor, with few rooms and crowded living conditions. Consequently, infectious diseases tend to spread quickly within larger households. However, having a higher proportion of adult women in a household may reduce childhood diarrhea incidence as children might get better care and more time, therefore resulting in improved health outcomes.

causes of under-five child mortality and morbidity, and contaminated drinking water is considered to be the major cause of diarrheal diseases.

The linkages between WASH, health outcomes and agriculture are crucial. In the context of the rural households in our study, we looked at two specific areas of such interactions. First, animal excreta can be a source of pathogens; therefore, keeping livestock may increase the risk of childhood diarrhea. The sampled households practiced mixed farming, and more than 97% of the households own livestock, which often share the same space with the people. All these factors are expected to result in a positive correlation between the presence of livestock and child diarrhea incidence, although it might be partly offset by the nutritional impacts of a more diverse (animal protein) diet. Importantly, we recorded not only livestock ownership, which could be used as a proxy for the wealth effect, but also the presence of livestock in/around the human living area. Second, we tested for the impact of irrigation on child diarrhea. The theoretical relationship between these two factors is unclear. The availability of irrigation water may allow households to use more water than households without irrigation, thus having a positive impact on sanitation activities and resulting in a lower diarrhea incidence among young children. However, the quality of irrigation water may create new sanitation and hygiene issues and therefore reduce the positive impact of water availability.

Finally, we controlled for basic child health parameters by using exclusive breastfeeding for the first 6 months of life as an indicator of parental care towards a child's health, which is strongly correlated with health outcomes.

Water, sanitation and hygiene

Improved household water quality is expected to reduce the risk of childhood diarrhea by acting as a barrier to disease-causing pathogens. The traveling and waiting time used for collecting water determines the amount of water collected by a given household and reduces the time available for child care and other activities. A recent empirical study has shown that the time spent on fetching water from distant sources for domestic use significantly affects child health (Pickering & Davis 2012). Insufficient water may also limit good hygiene practices, such as washing hands regularly at critical times. Overall, water collection time is assumed to be positively correlated with childhood diarrhea incidence. Finally, we controlled for the practice of handwashing with soap, which is a defensive mechanism to improve household health and therefore expected to be negatively correlated with diarrhea incidence.

3.4 Descriptive Statistics

Table 3 shows the descriptive statistics of variables of the sample households used in our empirical analysis.

Table 3: List of variables - definitions and summary statistics

Variables	Definition	N	Mean	SD
Household characteristics				
Household head age	Age of household head in years	454	37.72	8.64
Household head literacy	1=yes; 0=otherwise	454	0.44	0.50
Primary caretaker age	Age of primary caretaker in years	453	30.33	6.64
Primary caretaker literacy	1=yes; 0=otherwise	453	0.09	0.29
Highest education	The highest grade completed in a household	454	3.50	3.05
Adult female	# of female members aged 15 or older	454	1.22	0.49
Household size	# of household members	454	5.98	1.77
Under 5 years children	# of children under 5	454	1.24	0.45
Under 8 years children	# of children aged 7 or younger	454	1.99	0.72
Household density	# of persons per room	454	3.30	1.27
Dependency ratio	Share of household members aged <15 or >55	454	0.55	0.12
Per capita expenditure	Household per capita expenditure in local currency	454	316.50	134.16
Asset value	Household asset value in local currency	454	5996.99	6663.83
Under 5 child characteristics				
Age	Child age in months	562	29.02	16.30
Child male	1=male; 0=female	565	0.46	0.50
Breastfeeding (1=yes)	Exclusive breastfeeding for the first 6 months	562	0.69	0.46
Medical visit	# of medical visits in the past year	565	0.80	1.28
Water and sanitation				
Primary drinking water source	1=improved; 0=otherwise	454	0.50	0.50
Water quality (no *E.coli*)	1=safe; 0=otherwise	454	0.42	0.49
Minutes to water source	Time needed for one round trip	454	20.40	15.72
Time spent fetching water	Total time spent in minutes over the last 7 days per household	454	991.56	818.64
Water consumption	Per capita per day consumption (liters)	454	8.77	2.53
Water purification	1=yes; 0=otherwise	454	0.08	0.27
Water collection container	1=jerrycan; 0=claypot	454	0.83	0.37
Water user committee	1=yes; 0=otherwise	454	0.29	0.46
Pit latrine	1=yes; 0=otherwise	454	0.42	0.49
Safe child stool disposal	1=yes; 0=otherwise	454	0.36	0.02
Hygiene and health				
Handwashing with soap by primary caretaker	1=yes; 0=otherwise	454	0.27	0.45
Under-five child diarrhea	1=yes; 0=otherwise	562	0.16	0.36
Distance to health center	Distance in kilometers	20	5.20	4.08
Agriculture				
Irrigation practice	1=yes; 0=otherwise	454	0.67	0.47
Livestock	Total livestock units owned by the household	454	3.97	1.87

Sources: Authors' computation based on own survey data

The survey found that level of education is very low, although household heads are much better than the primary caretakers in terms of self-reported literacy (44% as opposed to 9%). Yet, very few household heads in our sample have completed primary school (less than 4%). This indicates that most of the respondents in this study are largely illiterate.

Other crucial descriptive statistics in Table 3 include water and sanitation infrastructure. While 50% of the households in our sample have access to improved water supply (based on the JMP definitions), about 58% of the households had contaminated drinking water at storage. The results suggest that the JMP definition of 'improved' drinking water sources overestimates access to improved drinking water when taking in consideration POU water safety or quality. The study also reveals that only 5% of the households had access to improved water source in their own yard or living area, and 34% of the households took 30 minutes or more for a round trip to obtain drinking water. As a result, households spent a considerable amount of time fetching water, on average about 2 hours and 22 minutes per day.

Improved sanitation facilities are virtually non-existent in rural communities of Ethiopia. About 42% of the households reported that they have simple pit latrines while 58% of the households defecate in the open. The reported open defecation rate is much higher than the rural national average open defecation rate of 43% (WHO/UNICEF 2014). Moreover, most adult women prefer defecating in a bush. The survey also revealed that more than 74% of the primary caretakers practiced open defecation for the last stool before the survey. As many of the latrines were constructed in response to a push by the local government, open defecation is still a norm and practiced by a majority of the population in the study areas. Further, again due to the limited awareness of the harmful nature of child stools, only 38% of last child stools preceding the survey were adequately disposed.[10] As Figure 3 shows, about 25% of the child stools were not removed safely. Studies have shown that sanitary disposal of fecal matters is an effective mechanism in reducing child morbidity (Curtis et al. 2000). Leaving child stools in the immediate vicinity or yard increases the risk of young children coming into direct contact with stools, which causes diarrheal diseases.

[10] A report also shows that there is clear difference between urban and rural areas in the way children's stools are disposed of. Nationally, a higher proportion of urban children's stools (63%) are disposed of safely than of rural children's stools (31%) (CSA & ICF International 2012).

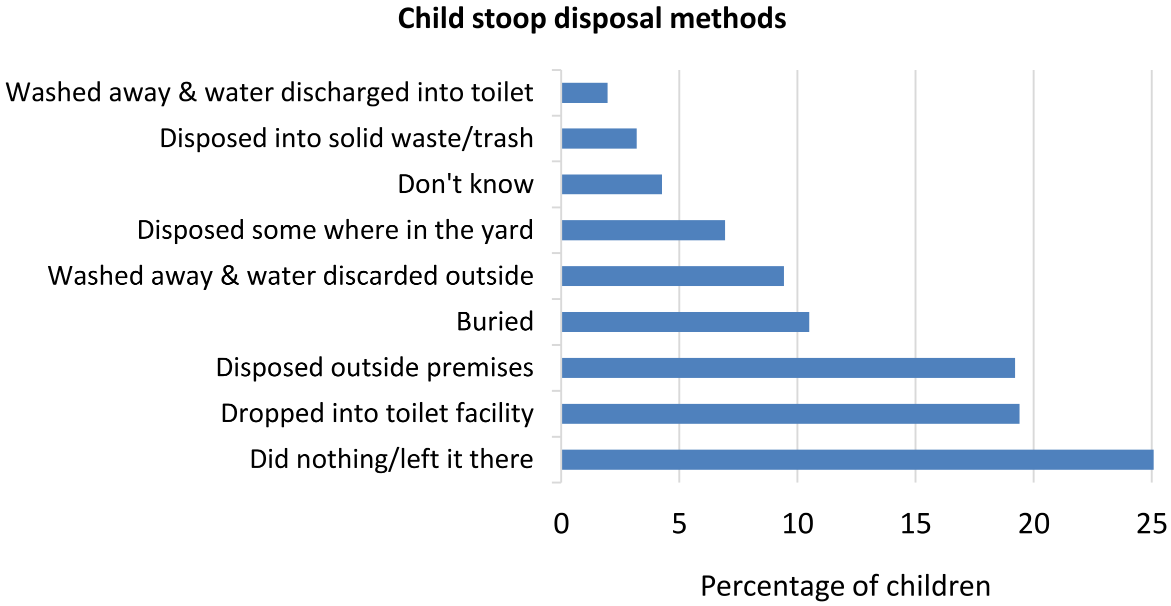

Figure 3: Method of disposal for the last child stool preceding the survey

Source: Authors' computation using survey data

3.4.1 Diarrhea as a child health problem

The result shows that 16% of under-five children were reported by their primary caretakers to have experienced diarrheal illness during the two week preceding the survey (Table 3). The incidence of child diarrhea in relation to child and parental education characteristics is presented in Table 4. Diarrhea incidence was higher among children younger than 24 months, particularly among those between 6 and 23 months old. Children aged between 36 and 47 months old were the least affected by diarrhea. However, there was no significant difference in diarrhea incidence by the sex of the child; boys were slightly more likely to have experienced diarrhea (16.34%) than girls (15.08%).

Surprisingly, the reported diarrhea incidence was low among the children with illiterate primary caretakers and household heads. We had expected that diarrhea incidence to decrease with increasing education levels and literacy of primary caretakers and household heads. This could have been the result of a lower level of school attainment. For example, only 4.3% of the household heads and 1.2% of the primary caretakers have completed primary school education. There is not much variation in the outcome of education. Also, this observation could also be due to primary caretakers who are illiterate having lower knowledge of the symptoms of childhood diarrhea.

Finally, children living in households with corrugated iron sheet roofing had lower diarrhea incidence than those living in households with thatch roofing (15.40% and 18.37% respectively). Although the physical characteristics of a household's environment often serve as indicators of the household's socioeconomic status, they are also considered to be an important determinant of the health of children and other household members (Cattaneo et al. 2009).

Table 4: Incidence of diarrhea in the last two weeks prior to the survey by demographic characteristics

Age of child (months)	Incidence of diarrhea (%)	Number of children
< 6	11.54	52
6 -11	30.36	56
12 -23	33.02	106
24- 35	12.03	133
36 – 47	4.10	122
48 - 59	9.96	93
Sex of child		
Male	16.34	257
Female	15.08	305
Primary caretaker's literacy		
Yes	17.39	46
No	15.50	516
Household head's literacy		
Yes	16.36	238
No	14.71	324
Housing roofing material		
Corrugated iron sheet	15.40	513
Thatch	18.37	49

Source: Authors' computation using survey data

3.4.2 The influence of improved water supply and sanitation on child diarrhea

Diarrhea incidence among under-five children by the household water and sanitation characteristics is presented in Table 5. Based on the WHO definition of improved water sources, children under the age of five living in households with unimproved water sources were more likely to have had diarrhea in the past two weeks (18.34%) than those living in households with improved water sources (12.82%). This result is consistent when broken down by detailed water sources. Children living in households with private protected water had lower diarrhea incidence compared to those living in households with shared protected water sources. This might be because water is more available to households with private protected water, therefore resulting in less interruption to because of long travelling distance. Moreover, since water is available near to their living area, household members, especially adult women, can use the time and energy saved to provide better care for their children. However, diarrhea incidence was much higher in households with contaminated POU water (24.46%) than household with uncontaminated POU water.

The hygiene habits of a child's caretaker were also an important factor. As shown in Table 5, the diarrhea incidence among children was lower if their caretaker practiced handwashing (18.02% as opposed to 9.55%). Diarrhea incidence was also higher among children whose households treated their drinking water, although the number of such households is small. Households that treated their water are likely have water sources with poorer quality than households that do not treat water. However, children in households treated their water had lower diarrhea incidence than those in households that did not treat their water. Households in the study areas seldom practiced water treatment. Slightly below 8% of households reported that they use some form of water treatment with 81% of these households applying chlorine-based methods to treat their water during the month preceding the survey. On the other hand, no significant difference in diarrhea incidence was observed between irrigating and non-irrigating households in the two weeks preceding the survey. There was also no significant difference in diarrhea incidence between households with and without a pit latrine.

Table 5: Incidence of diarrhea in the last two weeks prior to the survey by water, sanitation and hygiene characteristics

	Incidence of diarrhea (%)	**Number of children**
Water source based on WHO		
Improved source	12.82	273
Unimproved source	18.34	289
Water sources		
Private protected dug well	6.67	30
Shared protected dug well/spring	13.58	243
Unprotected well/spring	18.83	223
Surface water	16.67	66
Storage water quality		
Contaminated	24.46	327
Uncontaminated	3.4	235
Handwashing with soap		
Yes	9.55	157
No	18.02	405
Water purification/treatment		
Yes	5	40
No	16.48	522
Latrine		
Yes	15.41	231
No	16.02	331
Irrigation farming		
Yes	15.38	377
No	16.22	185

Source: Authors' computation using survey data

3.4.3 Health knowledge and hygiene awareness

While 77% of the primary caretakers thought that diarrhea can be prevented, most did not see that poor water quality and lack of proper hygiene and sanitation as potential causes of childhood diarrhea. In most of the cases, the primary caretakers considered contaminated food as the major cause of diarrhea in young children, followed by bad or poor water quality. While 15.42% of the primary caretakers did not know what causes diarrhea, other factors such as poor hygiene, dirty hands, flies and germs, and poor sanitation practices, were cited as major causes of high diarrhea incidence by the study participants (Table 5).[11]

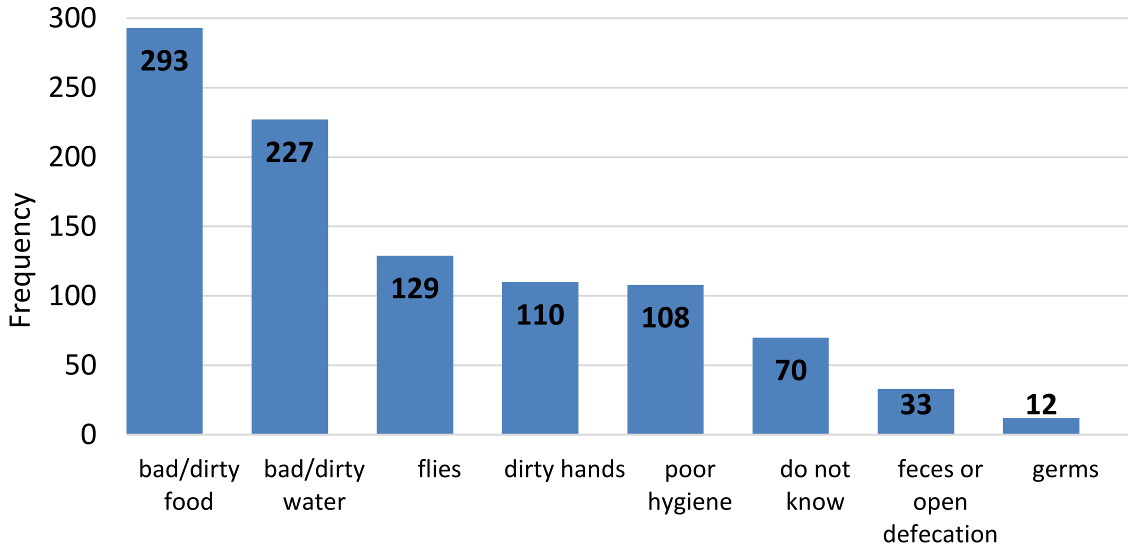

Figure 4: Causes of childhood diarrhea reported by the primary caretakers

Source: Authors' computation using survey data

[11] A report from the Mecha woreda health center, one of the study district, showed that pneumonia, diarrhea (non-bloody), malaria PF, acute febrile illness (AFI), acute upper respiratory infection, malaria PV and infection of skin were the top seven diseases morbidity for under-five years in 2013.

4 Empirical Strategy

This section outlines the empirical strategy employed to explain the impact of household drinking water quality and sanitation behavior on child health outcomes. The dependent variable indicates the self-reported diarrhea incidence in the two weeks preceding the survey. To identify a robust relationship between POU household water quality and health outcomes, the robustness of the results was examined using a range of estimation strategies.

Establishing the causal impact of drinking water quality on child health outcomes based on cross-sectional data is difficult as it requires a careful investigation of the treatment variable to address the possible endogeneity problem. For instance, endogeneity can arise where there is an unobserved covariate that determines both water quality and health outcomes.[12] In this analysis, POU drinking water quality was used as the treatment variable. Water quality was determined based on the results of the microbiological water sample tests during the data collection period. According to WHO guidelines for drinking water quality, water is considered unsafe or contaminated if the *E. coli* colony count per 100 ml of water is one or greater. In this case, however, endogeneity of sanitation variables was not an issue as we used village-level (neighborhood mean) indicators for both pit latrine and the disposal of child stools.

4.1 Instrumental Variable Approach

Given the likely endogeneity of POU household drinking water quality, it is difficult to infer the causal impact of water quality on health outcomes from cross-sectional data. In this paper, the impact of drinking water quality on child health outcomes was analyzed using a two-stage instrumental variables approach. For the first stage consider the following linear probability model:

$$W_{ij} = X_{ij}\beta_1 + Z_{ij}\eta_1 + N_j\mu_1 + \upsilon_{ij} \qquad (1)$$

where treatment W_{ij} of each household i in community j is predicted using a vector of household characteristics X_{ij} ; Z_{ij} is a vector of instrumental variables; N_j is a vector of sociodemographic factors, which is constant within a community j; and a nonsystematic error term υ_{ij}, which varies over households such that $E\left[\upsilon_{ij}\middle|X_{ij}, Z_{ij}, N_{ij}\right] = 0$. While β_1, η_1 and μ_1 are unknown parameters to be estimated in the first stage. The second stage

[12] Moreover, the water quality variable may be an endogenous regressor due to unobservable heterogeneity among household members or omitted variables which cannot be captured in our data affecting both household drinking water quality and health or measurement errors.

employs the predicted treatment status $\widehat{W_{ij}}$ from Equation 1 to estimate the treatment effect on outcome Y_{ij}, such that

$$H_{ijk} = X_{ij}\beta_2 + \widehat{W_{ij}}\theta + N_j\mu_2 + \varepsilon_{ij} \qquad (2)$$

where H_{ijk} denotes the outcome (e.g., diarrhea) for child k in household i and in community j, X_{ij} is a vector of household- and child-specific characteristics, and N_j are the same covariates as used in stage 1.

4.2 Bivariate Probit Estimator

As an alternative to the standard linear IV methods, Greene (2012) has shown that average treatment effects (ATE) can be obtained by a bivariate probit model (BP). The BP model is a two-equation binary outcome model with correlated error disturbances. The disturbance terms of the two equations are assumed to be jointly distributed as standard bivariate normal. In this approach, the models are estimated simultaneously using maximum-likelihood estimation.

To account for any potential selection effects, the endogeneity of treatment (W) and outcome (H) may be modelled jointly based on the assumption that the treatment has a direct causal impact on the outcome and both are influenced by common observable factors. Suppose H represents the observed health status of a child and takes a value of one if a child had diarrhea in the two weeks before the survey, and zero if otherwise, then the observed response variable H is related to an unobserved latent variable H^* as follows:

$$H_{ijk}^* = \alpha_{1i}X_{ij} + \alpha_{2i}W_{ij} + \varepsilon_{1i}$$

$$H_{ijk} = \begin{cases} 1 & if \quad H_{ijk}^* > 0 \\ 0 & otherwise \end{cases} \qquad (3)$$

where X is a vector of control variables; W is a dummy variable with a value of one if the water is not contaminated, and zero if otherwise; α_1 is a vector of parameters to be estimated; α_2 is the parameter of interest associated with the dummy variable; ε_{1i} is a residual term, with $E[\varepsilon_{1i}] = 0$ and $var[\varepsilon_{1i}] = 1$; and i indexes households.

Equation 3 gives an unbiased parameter estimate of α based on the assumption that W is an exogenous variable. But the validity of this assumption can be questioned because the observed variation in W may reflect the unobserved factors that also influence the outcome variable H. Within a given neighborhood, some households may have unobserved preferences that causes them to have better household water quality than other similar households (Koolwal & Van de Walle 2010). Therefore, a simplistic comparison of child health status between households with contaminated water and households with safe water would lead to biased results. To account for the endogeneity of the water quality variable W, the bivariate probit model was constructed as:

$$H_{ijk}^{*} = \alpha_{1i}X_{ij} + \alpha_{2i}W_{ij} + \varepsilon_{1i}$$

$$W_{ij}^{*} = \beta_{1i}X_{ij} + \beta_{2i}Z_{ij} + \varepsilon_{2i} \qquad (4)$$

$$W_{ij} = \begin{cases} 1 & if \;\; W_{ij}^{*} > 0 \\ 0 & otherwise \end{cases}$$

where W_{ij}^{*} represents a latent continuous variable, Z is a vector of instrumental variables, and by assumption we have $E[\varepsilon_{1i}] = E[\varepsilon_{2i}] = 0$ and $var[\varepsilon_{1i}] = var[\varepsilon_{2i}] = 1$ with $cov[\varepsilon_{1i}\varepsilon_{1i}] = \rho$. Rho measures the correlation between omitted or unobserved factors in the health and water quality equations (Wooldridge 2010). β_1 and β_2 are vectors of parameters to be estimated, and a Wald test can be applied to ρ to test for the exogeneity of W. If ρ is significantly different from zero, then we can estimate the two equations jointly with a bivariate probit approach using maximum likelihood (ML) and it will produce consistent estimates. Here, we estimated a recursive bivariate probit model whereby water quality appeared as a regressor in the health outcome equation.[13]

[13] Generally, Nichols (2011) showed that in case of a binary regression with a binary endogenous variable linear IV generates robust consistent estimates of the ATT (average treatment on the treated) while bivariate probit produces efficient estimates of the ATE.

5 Estimation Results and Discussion – the Impacts of Water Quality and Sanitation on Child Health

To address the possible endogeneity of POU water quality, we proposed two variables as instruments for the treatment variable. The first instrument is the type of primary sources from which households fetch their drinking water. In the study areas, most of the population take water from community water sources, and a majority of rural households do not have alternative drinking water sources. In our sample, only 5% of the households have access to an improved private water sources in their living area. The second instrument is the existence of water user group/committee in the village. We asked households whether there is a water user group responsible for taking care of community water sources in the village. Water user groups are primarily responsible for monitoring, supervising and handling conflicts among household users of community water sources. Such groups are instituted in many villages for governing rural communal water sources when a new water source is developed. For instance, 62% of the villages in Mecha district had water user groups (Tilahun et al. 2013). Water source and water user group can both be treated as exogenous variables in the context of this study as they do not affect child health outcomes directly.

The impact of safe water and sanitation behavior on childhood diarrhea estimation is presented in Table 6 (the full regression results that show all the coefficients for columns 3, 5 and 7 are presented in Table A.1 in the appendix). In Table 6, columns 1 to 3 report the linear probability model (OLS) and the binary probability model (Probit), which do not take into account any endogeneity problem. Estimating the “naïve” model helps to examine the extent to which our results are sensitive to the assumption that storage water quality is an exogenous variable. Columns 4 to 7 show the standard instrumental variable (IV) models and the recursive bivariate probit (BP) models. As the regression results show, drinking water quality, safe child stool disposal and latrine density significantly affected child diarrhea incidence in all model specifications. The estimates of other relevant variables coefficients are also statistically significant with the expected signs across all specifications.

Both the linear IV and BP two-stage models require a strong treatment prediction in the first stage. The first-stage regressions showed statistically significant relationship between the treatment and instrument variables (Table A.2). This relationship is robust with and without second-stage controls. The r-squared is modest, and a large F-statistics in the first-stage regression suggests bias from weak instruments is unlikely to be a problem. For the linear IV model, the over-identification restriction test regarding the instruments is not violated ($p=0.88$), which implies that we can reject the null hypothesis that at least one of the instruments is invalid. On the other hand, considering the exogeneity test for household water quality, Wooldridge’s score test does not reject the null hypothesis that water quality is exogenous at conventional significance level (p=0.71), as presented in Table A.2. Even if household water quality were exogenous, the linear IV estimates are still consistent but are less efficient than the least squared estimates.

Moreover, the exogeneity test from the BP framework, as shown in columns 6 and 7 (Table 6), indicated that $\widehat{\rho}$ is not statistically different from zero (p=0.51). The result indicated that the error terms are independent and the water quality is exogenous. In other words, the BP model is equivalent to two independent probit models. Therefore, we can treat household water quality as exogenous.

Table 6: Health effects of water quality and sanitation habits: Diarrhea in under-five children

VARIABLES	(1) OLS	(2) PROBIT	(3) PROBIT	(4) 2SLS	(5) 2SLS	(6) BP	(7) BP
Water quality (1= no *E.coli*)	-0.145***	-0.159***	-0.160***	-0.123**	-0.140**	-0.122**	-0.133**
	(0.028)	(0.031)	(0.031)	(0.058)	(0.060)	(0.061)	(0.066)
Child age (months)	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender (male=1)	0.010	0.008	0.008	0.010	0.010	0.008	0.008
	(0.026)	(0.021)	(0.021)	(0.025)	(0.025)	(0.021)	(0.021)
Mother age	-0.063***	-0.052***	-0.051***	-0.063***	-0.062***	-0.051***	-0.051***
	(0.021)	(0.016)	(0.016)	(0.021)	(0.021)	(0.016)	(0.016)
Mother age square	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Highest education	0.002	0.000	-0.000	0.002	0.002	-0.001	-0.001
completed	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)
Number of adult female	-0.063*	-0.068*	-0.067*	-0.066**	-0.063*	-0.070*	-0.069*
	(0.032)	(0.038)	(0.039)	(0.034)	(0.034)	(0.036)	(0.037)
Exclusive breastfeeding	-0.082***	-0.068***	-0.068***	-0.082***	-0.084***	-0.067***	-0.067***
	(0.027)	(0.022)	(0.022)	(0.026)	(0.027)	(0.022)	(0.022)
Number of medical visit	0.044***	0.034***	0.034***	0.044***	0.044***	0.034***	0.034***
	(0.014)	(0.009)	(0.009)	0.013	(0.013)	(0.009)	(0.009)
Minutes to water source	0.002*	0.002**	0.002**	0.002*	0.002*	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Handwashing with soap	-0.059*	-0.059*	-0.059*	-0.062*	-0.060*	-0.063*	-0.062*
	(0.032)	(0.033)	(0.032)	(0.032)	(0.033)	(0.034)	(0.034)
Safe child stool disposal	-0.215***	-0.232***	-0.235***	-0.215***	-0.222***	-0.232***	-0.233***
(Neighborhood mean)	(0.069)	(0.077)	(0.083)	(0.067)	(0.072)	(0.076)	(0.083)
Latrine density	0.130*	0.131**	0.123**	0.125**	0.118**	0.123**	0.118**
(Neighborhood mean)	(0.065)	(0.060)	(0.054)	(0.063)	(0.058)	(0.060)	(0.055)
Distance to health center			-0.000		-0.001		0.000
			(0.004)		(0.004)		(0.004)
Other control variables	YES	YES	YES	YES	YES	YES	YES
Observations	562	562	562	562	562	562	562
Model F-Test	12.86						
Model Chi2		219.94	230.29	262.64	275.44	807.02	1235.36
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Probit rho chi2						0.43	0.19
Probit rho p-value						0.51	0.66

Robust standard errors adjusted for clustering at village level in parentheses;
Significance *** p<0.01, ** p<0.05, * p<0.1
Probit and BP in average marginal effects

Other control variables: household head age, household density, dependency ratio, exclusive breastfeeding, number of medical visits, livestock units, household asset, irrigation practices, per capita expenditure and number of children aged 7 or younger.

In the preferred probit model (column 2 of Table 6)[14], safe storage water and safe child stool disposal decreased the incidence of child diarrhea, whereas a higher pit latrine density increased the risk of diarrhea for under-five children in all model specifications. The impact of safe drinking water on child diarrhea incidence was modest and statistically significant at 5% level, with a marginal effect of 0.16; that is, the probability of child diarrhea was 16 percentage points lower in households with safe household drinking water. Safe child stool disposal decreased child diarrhea incidence by 23%, and pit latrine density increased it by 13%. The finding that neighborhood pit latrine concentration increased the risk of diarrhea in young children casts serious doubt on the assumed health and social benefits of moving from open to fixed-location defecation.

Regarding the control variables, most of the estimated coefficients had the expected signs. Child age is significant and negative, implying a reduction of diarrhea incidence as a child grows older.[15] In terms of gender, male and female children are equally affected by diarrhea. The relationship between a mother's age and diarrhea incidence in her children is nonlinear, and this indicated that children with a younger mother tend to fall ill more often. However, the age of a household head had no significant impact on childhood diarrhea incidence. Also, the level of household education showed no clear effect. This is because usually only the primary caretaker's level of education plays an important role in improving child health.

Time to water source was marginally significant at 10% level, but the estimated effect on diarrhea incidence was much smaller than some of the estimates reported in the existing literature in sub-Saharan Africa (Pickering & Davis 2012). Distance to the water source also affected the quality and quantity of water a household could collect. The farther a water source from home, the less water a household could collect and use. This evidence further suggested that the health benefits of having access to improved water may not be substantial if water sources are further away from the house and therefore requiring considerable time and energy to fetch the water. Moreover, closer proximity to a water source could have an indirect health benefit. By reducing the time spent on collecting water, more time is available for looking after children or engaging in other productive and income-generating activities. In terms of hygiene behaviors, we also found that handwashing with soap improves child health outcomes. Handwashing with soap is considered to be an effective defensive behavior to remove germs and pathogens from hands.

[14] The probit regression model is preferred because it is more efficient than the 2SLS or BP when there is no endogeneity.

[15] Child age-squared term was excluded in the regression as it is not statistically significant, but children between 6 and 24 months old were the most affected age group in this study.

Children belonging to a household with greater number of adult women seemed to be better off (Table A.1). It can be argued that children with an additional adult woman get better care. The household density variable had a positive sign and was statistically significant at 1% level. It was expected that the relative disease burden would increase in households living in congested or overcrowded conditions. It seemed plausible that children living under such conditions are more exposed to health risks. Moreover, children in larger families are more exposed to health risks also because of the larger number of hand-to-water pathogen transmission pathways. On other hand, household dependency ratio did not have any significant effect on child health.

Exclusive breastfeeding also had a significant effect (7%) on diarrhea incidence in young children. We expected a much stronger effect for children under-three years than under-five years but the impact is the same. This variable is also more likely to suffer from recall bias or measurement error. The number of medical visits in the previous year significantly increased with diarrhea incidence. This variable is used as a proxy for the general health status of a child in the previous year. We expected that children who often fall sick have a weak immune system and are therefore more susceptible to diarrheal diseases.

We could not find any significant difference in childhood diarrhea incidence between irrigating and non-irrigating households. However, livestock ownership increased diarrhea incidence, and its coefficient was statistically significant at 5% level. On the other hand, we expected children from wealthier households to be better off than those from poorer households because higher income allows a household to access better health services and invest in measures that improve their health. This indicated that high asset value (wealth) does not make children immune from contracting diarrheal diseases in the study areas. Distance to the nearest health center did not have any significant impact on health either. It is evident from the study that drinking water quality, sanitation, handwashing and breastfeeding habits are very important factors in determining the risk of childhood diarrhea.

Our findings regarding the health effects of latrine contradict the claim that moving from open defecation to the first ladder of sanitation services generates the greatest amount of benefits from sanitation services. There could be a few reasons for this apparent paradox: first, pit latrine attracts flies, which are vectors of pathogens that can transmit diseases through direct contact with young children or food; second, we also found that availability of latrine deteriorates POU water quality, particularly for households whose water sources are located within the living area. The sub-sample analysis presented in Table A.3 in the appendix showed that the concentration of *E. coli* is significantly higher in households whose water source was located near their living area, even after controlling for other household characteristics ($p=0.005$). Well water may be polluted by leachates from latrines if the latrines are not located sufficiently far away from water sources. Other studies have shown that in rural areas, latrines can be a source of ground water pollution (for a detail discussion see, Banks et al. 2002; Graham & Polizzotto 2013). Poorly maintained latrines can generate negative externalities which affect not only its owner but also the neighboring communities. There must be a shift in government policy away from building simple pit latrines to create open defecation free villages in rural areas because it may not generate the desired health benefits from sanitation services. Existing latrines should be upgraded to make them safe and hygienic as simply adopting pit latrines may worsen a community's health status at large.

Generally, our study highlighted the fact that storage water quality and sanitation issues are a great public health concern in rural Ethiopia. Infants and young children are more likely to suffer from water- and fecal-related diseases than any other age groups. Promoting the following among the rural communities could substantially reduce the transmission of germs and pathogens that can cause diarrhea and other infectious diseases: 1) washing the hands of caretakers and children with soap at critical times, 2) adequate household water treatment and safe handling of water, 3) safe disposal of stools, and 4) good hygiene practices when feeding and handing food. On the one hand, women are primarily responsible for collecting water for household use and other household chores, and they are often the ones reinforcing hygiene practice at home. On the other hand, the level of education in the study areas is very low, especially for mothers (primary caretakers). Primary caretakers and women are therefore an important target group of any WASH-related interventions for them to be effective in reducing overall diseases burden.

There are few limitations in this study. One of the main limitations of the study is our reliance on the primary caretakers' opinions on what constitutes childhood diarrhea for our data. The study would have given more insights if actual medical records were collected from the districts health centers and posts. However, reliable morbidity data for diarrheal morbidity are difficult to obtain from local health center and posts due to lack of adequate health care services in rural areas. Further, the study would have been benefited if water sample quality tests were repeated for certainty and samples were collected from all possible water sources. Our subjective judgment regarding the quality of water at its source based on the WHO definition may be misleading as most of the protected community water sources were contaminated with *E. coli*. For instance, among the 29 protected community water sources, our water sample testing results showed that 58% of them were contaminated with *E.coli* (not discussed here).

Robustness

The impacts of drinking water quality, safe stool disposal and latrines on child diarrhea incidence are robust to model specifications and age. The result of the subsample analysis for under-three children (presented in Table A.4) showed that good water quality and proper child stool disposal have a larger positive impact on younger children, while the impact of latrine density remained the same. Moreover, the fact that almost all the results are statistically not different from one another is surprising. With the regression estimates shown in Table A.5, we measured the effects of latrines at household level, and the results showed that latrines had still a strong positive impact (8%) on child diarrhea incidence. However, the effects of water quality on child diarrhea is not big when *E. coli* coliform counts are considered as a continuous variable (presented in Table A.6). Moreover, the way we defined 'safe child stool disposal' created some correlation between the variables 'safe child stool disposal' and 'latrine'. However, it did not cause much problem because less than 20% of the households used toilet to dispose of child stool.

6 Conclusions and Recommendations

Using a combination of estimation methods, this study examined the impact of household drinking water quality and sanitation behavior on child health in rural Ethiopia. Diarrhea was used as a health outcome. In this paper, we focused on children under the age of five because children in this age group are the most vulnerable to water- and fecal-related diseases. The study relied on primary survey data from rural areas in Fogera and Mecha districts of Ethiopia. As access to clean water and improved sanitation is lucking, water-related diseases are the most prevalent health problem in the study areas.

A number of studies have been conducted to quantify the impact of safe drinking water on child health. However, still very little is known about it in the context of rural areas, where access to improved water is very limited and the majority of the population rely on unimproved water sources. One of the innovations of this paper is that household drinking water quality was determined by testing the microbiological quality of household storage water using membrane filtration method rather than looking at the types of household drinking water sources.

Inadequate access to improved water and sanitation facilities remains a major cause of health problems in Ethiopia, particularly in the rural areas, where a lack of clean drinking water and unsafe sanitation practices are the main causes of diarrheal diseases among under-five children (CSA and ORC Macro 2006). The negative health impact of contaminated water is worsening because most rural households only have access to drinking water from unprotected sources and they often consume the water without any in-house treatment. Moreover, most of the rural population have a poor understanding of the importance of proper hygiene practices, which further increases their already high risk of contracting infectious diseases.

The findings suggest that access to an improved drinking water source is low in the study areas – only 50% of the households have access to improved water sources. The household water sample test also indicated that poor POU water quality is a significant problem in rural Ethiopia. Beside the fact that most of the so-called 'improved' water sources in rural areas do not guarantee the water is safe for consumption, the problem of unsafe drinking water is exacerbated by POU water contamination through unsafe water storage and handling practices. Even though access to clean water and simple pit latrines has increased significantly during the last decade, many of the surveyed rural residents did not regard the progress as satisfactory in terms of access to clean water supply. Rural households complained about a lack of access to safe water sources, poor water quality, and having to travel long distances to access drinking water.

In terms of sanitation, we found that 42% the households were equipped with a simple pit latrine while the rest of our sample households defecated in the open. Access to improved sanitation facility is virtually non-existent in the study areas, and the existing sanitation technology used there is considered unimproved based on the commonly used WHO definition. In some cases, these latrines do not have proper structure and become dysfunctional for many reasons, including the fact that they are not connected to any sewerage system.

Surprisingly, neighborhood latrine concentration increased the risk of childhood diarrhea. We found that children living in neighborhoods with high latrine density are at higher risk of contracting diarrheal disease. This indicates that existing pit latrines are not safer to use (none fly-proof and unhygienic) and do not protect against diarrheal diseases. Others have argued that the greatest benefit of sanitation, for both health and social reasons, can be achieved when people move from open to fixed-location defecation (Mara et al. 2010). However, contrary to the belief of many, our study suggests that in a rural setting, where settlements are scattered, defecating in the open might not be more harmful than using a simple pit latrine. Nevertheless, we are not encouraging open defecation per se, but rather arguing that simple pit latrines are not good enough to achieve the desired health benefits of sanitation. A study by Cameron (2009) conducted in Ethiopia also found using pit latrines offered no improvement over defecating in the open in terms of health outcomes.

A number of policy recommendations can be derived from these findings. First, more efforts should be put into increasing the existing coverage of improved rural water supply. This can be achieved by developing new water points and upgrading existing unimproved sources. Improving access to clean water supply not only increases the quantity of clean water available for household consumption but also allows households to save much time by reducing the distance between each household and the nearest water access point. Second, pit latrines should only be adopted if adequate hygiene can be maintained, otherwise they can pose a serious health risk, especially if they are not fly-proof or insufficiently away from water wells. Third, a water quality monitoring system which monitors a set of common water quality indicators should be in place to ensure rural water supply schemes comply with quality standards. Fourth, household water treatment and safe water storage should be promoted to address POU water quality concerns. Increasing the provision of rural water supply alone may not be enough if households do not treat their water or practice safe water storage and handling. We therefore recommend all rural households to develop the habits of household water treatment to ensure safe water quality – particularly for consumption. Fifth, households should be made aware of the importance of safe WASH through educational campaigns so as to help them change their long-held habits and hygiene behaviors. As the study revealed, when primary caretakers consistently practice handwashing with soap at critical times and safe child stool disposal, the risk of young children contracting diarrhea was reduced. Therefore, educating rural communities on the potential sources of water contamination, proper water treatment methods, safe disposal of feces away from the domestic environment, and good hygiene practices (such as handwashing with soap at critical times) could result in significant health gains to the rural population. At the same time, containers used for collecting or storing water need to be cleaned regularly to ensure safe water quality.

On a policy level, our findings indicate that WASH interventions are also needed to improve household water treatment, water collection time, safe sanitation and hygiene practices in rural areas. Primary caretakers often undermine the critical role that good hygiene plays in improving overall health outcomes. In addition to affecting health, inadequate water supply may cause households to limit their handwashing practices and to wash dishes and clothes using water from unimproved sources. The study also highlights that proper child stool disposal behavior is lacking. Most of the households perceived child feces to be less harmful than adult ones, and child feces were therefore often left around or disposed close to a household's living area. This further highlights the lack of awareness among the study households about the causes of diarrhea and the necessary remedial measures. Moreover, many primary caretakers do not consider diarrhea to be a serious health problem as it is common among young children. Education and public awareness campaigns could be an effective channel to disseminate information that can reduce child morbidity associated with poor WASH. This is particularly important in many rural areas of the country, where mothers usually have very little education. Such campaigns can be implemented on the ground by health extension workers. Proper hygiene and childcare practices can be promoted through the Ethiopian government's Health Extension Program (HEP) in many rural villages of Ethiopia. A report on rural water supply in Ethiopia found that most rural water sources were poorly maintained and often contain water unsafe for drinking; in some instance, water sources were not functioning due to repair and maintenance problems (UNDP 2006). Poor people are the ones suffering the most from the burden of diseases associated with a lack of clean water supply and sanitation services. The poor also lack awareness about the detrimental health impacts of poor water quality, unsafe sanitation habits and inadequate hygiene practices. Our descriptive statistics provided clear evidence that most rural households practice unsafe child stool disposal, inadequate household water treatment and improper hygiene.

Finally, to address the problem of WASH, Ethiopia has committed to the Millennium Development Goals (MDGs) by adopting the Universal Access Plan to achieve 100% water and sanitation coverage at national level. However, the overall progress has been slow and there is a disparity in development between urban and rural areas. The WHO/UNICEF (2015) report on the progress on water supply and sanitation showed that in 2015, 57% of the population have access to improved water sources (compared to 13% in 1990) and 28% of the population have access to improved sanitation services (compared to 3% in 1990). It is clear that sanitation coverage is lagging far behind water supply coverage. There should be more concerted and coordinated actions to meet the Sustainable Development Goal (SDG) 6 which aims to ensure access to water and sanitation for all. Unless efforts to increase access to clean water supply and sanitation services are intensified and implemented in conjunction with the promotion of proper hygiene practices, communicable diseases will continue to remain a major cause of child morbidity and mortality in rural Ethiopia.

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Appendix A Regression tables

Table A.1: Health effects of water quality and sanitation habits: Diarrhea in under-five children

VARIABLES	(1) POBIT	se	(2) 2SLS	se	(3) BP	se
Water quality (1= no *E.coli*))	-0.160***	0.031	-0.140**	0.060	-0.133**	0.066
Child age (months)	-0.004***	0.001	-0.004***	0.001	-0.004***	0.001
Gender (male=1)	0.008	0.021	0.010	0.025	0.008	0.021
Mother age	-0.051***	0.016	-0.062***	0.021	-0.051***	0.016
Mother age square	0.001***	0.000	0.001***	0.000	0.001***	0.000
Head age	-0.003	0.003	-0.003	0.003	-0.003	0.003
Highest education completed	-0.000	0.005	0.002	0.006	-0.001	0.005
Number of adult female	-0.067*	0.039	-0.063*	0.034	-0.069*	0.037
Household density	0.036***	0.012	0.048***	0.019	0.037***	0.012
Dependency ratio	0.125	0.151	0.126	0.169	0.118	0.148
Exclusive breastfeeding	-0.068***	0.022	-0.084***	0.027	-0.067***	0.022
Number of Medical visit	0.034***	0.009	0.044***	0.013	0.034***	0.009
Minutes to water source	0.002**	0.001	0.002*	0.001	0.002**	0.001
Handwashing with soap	-0.059*	0.032	-0.060*	0.033	-0.062*	0.034
Number of livestock units	0.015**	0.007	0.017**	0.008	0.016**	0.008
Irrigator household (1=yes)	-0.026	0.039	-0.016	0.038	-0.025	0.039
Asset value	-0.000	0.000	-0.000	0.000	-0.000	0.000
Safe child stool disposal (Neighborhood mean)	-0.235***	0.083	-0.222***	0.072	-0.233***	0.083
Latrine density (Neighborhood mean)	0.123**	0.054	0.118**	0.058	0.118**	0.055
Per capita expenditure	-0.000	0.000	-0.000	0.000	-0.000	0.000
Children 7 year or under	-0.017	0.020	-0.020	0.021	-0.017	0.020
Distance to health center	-0.000	0.004	-0.001	0.004	0.000	0.004
Observations	562		562		562	
Model Chi2	230.29		275.44		1235.36	
Model p-value	0.000		0.000		0.000	
Probit rho chi2					0.19	
Probit rho p-value					0.66	

Robust standard errors adjusted for clustering at village level; Significance *** p<0.01, ** p<0.05, * p<0.1
Probit and BP in average marginal effects

Table A.2: Household water quality, First-stage regression

VARIABLES	(1)	(2)	(3)	(4)
	LEAST SQUARES		PROBIT	
Water source (1=improved)	0.134**	0.124**	0.127***	0.114***
	(0.055)	(0.049)	(0.049)	(0.042)
Water user committee	0.383***	0.334***	0.337***	0.275***
	(0.060)	(0.058)	(0.048)	(0.044)
Observations	565	562	565	562
Stage 2 controls	NO	YES	NO	YES
R-squared	0.19	0.31		
Model F-Test	53.37	21.50		
Model Chi2				
Instruments jointly p-value	0.000	0.000	0.000	0.000
Basmann over-identification p-value	0.88	0.97		
Wooldridge's endogeneity score test p values	0.71	0.93		

Robust standard errors adjusted for clustering at village level in parentheses; Significance *** p<0.01, ** p<0.05, * p<0.1
Probit in average marginal effects

Table A.3: Impact of latrine on household water quality: Number of *E. coli* counts per 100/ml water

VARIABLES	(1)	(2)
	LEAST SQUARES	
Latrine (1=yes)	24.708***	22.119***
	(6.509)	(6.359)
Protected well (1=yes)	-17.619**	-18.318***
	(6.941)	(6.791)
Primary caretaker age		0.622
		(0.543)
Highest education completed		-1.573
		(1.294)
Adult woman		-19.797**
		(9.432)
Household density		4.148*
		(2.207)
Dependency ratio		-61.614
		(38.275)
Children younger than 8		12.010**
		(5.427)
Livestock units		4.853**
		(1.887)
Irrigator household (1=yes)		-0.945
		(8.900)
Asset value		-0.000
		(0.000)
Observations	92	92
R-squared	0.19	0.41
Model F-Test	10.28	5.140
Model p-value	0.000	0.000

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4: Health effects of water quality and sanitation habits: Diarrhea in under-three children

VARIABLES	(1) PROBIT	se	(2) PROBIT	se
Water quality (1= no *E.coli*))	-0.213***	0.042	-0.214***	0.042
Child age (months)	-0.005***	0.002	-0.005***	0.002
Gender (male=1)	0.014	0.031	0.013	0.031
Mother age	-0.057**	0.023	-0.056**	0.023
Mother age square	0.001***	0.000	0.001***	0.000
Head age	-0.005	0.004	-0.005	0.004
Highest education completed	0.002	0.007	0.001	0.007
Number of adult female	-0.070	0.052	-0.068	0.052
Household density	0.038**	0.016	0.038**	0.017
Dependency ratio	0.037	0.183	0.062	0.205
Exclusive breastfeeding	-0.068*	0.036	-0.068*	0.036
Number of Medical visit	0.043***	0.013	0.043***	0.013
Minutes to water source	0.002**	0.001	0.002**	0.001
Handwashing with soap	-0.056	0.043	-0.055	0.043
Number of livestock units	0.014	0.011	0.013	0.011
Irrigator household (1=yes)	-0.053	0.047	-0.054	0.048
Asset value	-0.000	0.000	-0.000	0.000
Safe child stool disposal (Neighborhood mean)	-0.313***	0.097	-0.306***	0.105
Latrine density (Neighborhood mean)	0.125**	0.064	0.127**	0.063
Per capita expenditure			0.000	0.000
Children 7 years/ under			-0.008	0.024
Distance to health center			0.001	0.005
Observations	361		361	
Pseudo R-squared	0.31		0.31	
Model Chi2	149.81		250.54	
Model p-value	0.000		0.000	

Robust standard errors adjusted for clustering at village level; Significance *** p<0.01, ** p<0.05, * p<0.1
Probit in average marginal effects

Table A.5: Health effects of water quality and sanitation habits: Diarrhea in under-five children

VARIABLES	(1) PROBIT	se	(2) PROBIT	se
Water quality (1= no *E.coli*))	-0.159***	0.032	-0.159***	0.032
Child age (months)	-0.004***	0.001	-0.004***	0.001
Gender (male=1)	0.010	0.020	0.010	0.020
Mother age	-0.054***	0.017	-0.054***	0.017
Mother age square	0.001***	0.000	0.001***	0.000
Head age	-0.004	0.003	-0.004	0.003
Highest education completed	-0.000	0.005	-0.000	0.005
Number of adult female	-0.071*	0.039	-0.070*	0.040
Household density	0.037***	0.011	0.038***	0.012
Dependency ratio	0.114	0.131	0.171	0.154
Exclusive breastfeeding	-0.069***	0.022	-0.069***	0.022
Number of Medical visit	0.034***	0.009	0.034***	0.009
Minutes to water source	0.002**	0.001	0.002**	0.001
Handwashing with soap	-0.062*	0.033	-0.062*	0.033
Number of livestock units	0.015**	0.008	0.015*	0.008
Irrigator household (1=yes)	-0.036	0.039	-0.029	0.040
Asset value	-0.000	0.000	-0.000	0.000
Safe child stool disposal (Neighborhood mean)	-0.196***	0.073	-0.211***	0.074
Latrine (1=yes)	0.081**	0.034	0.076**	0.031
Per capita expenditure			-0.000	0.000
Children 7 year or under			-0.019	0.020
Distance to health center			-0.001	0.005
Observations	562		562	
Pseudo R-squared	0.33		0.33	
Model Chi2	219.95		215.74	
Model p-value	0.000		0.000	

Robust standard errors adjusted for clustering at village level; Significance *** p<0.01, ** p<0.05, * p<0.1
Probit in average marginal effects

Table A.6: Health effects of water quality and sanitation habits: Diarrhea in under-five children

VARIABLES	(1) POBIT	se	(2) POBIT	se
Water quality (log (1+*E.coli*))	0.064***	0.006	0.065***	0.006
Child age (months)	-0.003***	0.001	-0.003***	0.001
Gender (male=1)	0.005	0.019	0.004	0.019
Mother age	-0.033**	0.016	-0.032**	0.016
Mother age square	0.001**	0.000	0.001**	0.000
Head age	-0.003	0.003	-0.003	0.003
Highest education completed	-0.000	0.005	-0.000	0.005
Number of adult female	-0.039	0.036	-0.038	0.036
Household density	0.018*	0.010	0.018*	0.010
Dependency ratio	-0.010	0.113	0.048	0.132
Exclusive breastfeeding	-0.055***	0.019	-0.056***	0.019
Number of Medical visit	0.026***	0.009	0.027***	0.009
Minutes to water source	0.001*	0.001	0.001*	0.001
Handwashing with soap	-0.018	0.026	-0.019	0.026
Number of livestock units	0.004	0.006	0.004	0.006
Irrigator household (1=yes)	-0.040	0.035	-0.037	0.034
Asset value	-0.000	0.000	-0.000	0.000
Safe child stool disposal (Neighborhood mean)	-0.201***	0.073	-0.205***	0.079
Latrine density (Neighborhood mean)	0.143***	0.054	0.134***	0.050
Per capita expenditure			-0.000	0.000
Children 7 year or under			-0.018	0.016
Distance to health center			-0.001	0.004
Observations	562		562	
Pseudo R-squared	0.44		0.44	
Model Chi2	277.24		319.98	
Probit rho p-value	0.000		0.000	

Robust standard errors and adjusted for clustering at village level;
Significance *** p<0.01, ** p<0.05, * p<0.1
Probit and BP in average marginal effects

Appendix B Variables definition

Outcome variables

Diarrhea Binary variable indicating a self-reported diarrhea incidence for under-five children in the two weeks before the survey

Water quality Binary variable indicating whether the drinking water from the point-of-use (POU) is contaminated with *E. coli* or not.

Socio-demographic characteristics

Household size the total number of household members

Dependency ratio number of household members younger than 15 or older than 60 divided by the total number of household members

Household density number of household members divided by the total number of living rooms.

Highest education completed the highest level of education completed by any one of the household members.

Handwashing with soap: Binary variable indicating whether the primary caretaker used soap for handwashing during the handwashing demonstration.

Village /community characteristics

Latrine density the proportion of households with a pit latrine in their village/cluster

Safe stool disposal the proportion of households who adequately dispose of child stools the last time preceding the survey. Following the Demographic and Health Survey standard, safe stool disposal is defined as discarding stools into a toilet facility, washing away stools and subsequently discharging the wash water into a toilet, or burying stools; other disposal methods are considered as unsafe.

Distance to health center the distance between the nearest health facility and the center of a kebele in kilometers