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This paper examines the short term impact of improved access to safe water on adult health and time allocation at newly constructed boreholes in rural Zambia. We employ a difference-in-differences estimation using a dataset collected under a quasi-experimental setting. We observe a significant effect of improved access to safe water on reduction of diarrheal incidence for working-age adults and a resulting decrease in the number of days during which they could not perform their regular activities due to diarrhea, although the economic benefits resulting from health impacts were very limited. With respect to time allocation, we find that improved access to safe water reduced time spent on water-related household chores, including fetching water for female adults who live with female children, suggesting that burden of water-related household chores shifted from female adults to young girls. We do not observe any significant increase in time spent on income-generating activities. Instead, the time-gain benefit for working-age adults can be found in leisure time, particularly among females who live near the new boreholes.

Keywords; fetching water; borehole, diarrhea; time use; groundwater development; Zambia

JEL Classification Codes: I38, J22, J16

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1. Introduction

Ensuring access to safe water is one of the major policy challenges in sub-Saharan African countries, where the majority of the population suffers from the least-improved water resources in the world. The proportion of people enjoying basic water services increased from 46% in 2000 to 61% in 2017 but remains below the worldwide average of 90%.[1] Despite decades of efforts to ensure the accessibility of safe drinking water, 207 million people are still reliant on water sources where collection times exceeded 30 minutes in 2017. Of these, 135 million people live in sub-Saharan countries, where access to safe water is severely restricted, particularly in rural areas.

This harsh reality is well recognized by international organizations and governments. The United Nations (UN) Sustainable Development Goals (SDGs) aim to "[E]nsure access to water and sanitation for all" by 2030 (Goal 6) and call for ensuring universal and equitable access to safe and affordable drinking water for all by then (Goal 6.1) (United Nations, n.d.). The importance of access to safe water has been reaffirmed by the outbreak of the COVID-19 pandemic in 2020, since hand-washing is considered an effective way to prevent infections including the COVID-19 virus.

This paper examines the short-run impact of improved access to very safe safe water sources on adult health and time allocation resulting from a groundwater

[1] There are five "ladders" at the water service level; "Safely managed" service is drinking water from an improved water source located on the premises, available when needed and free from faecal and priority chemical contamination. "Basic" service, which is defined as a part of SDG Goal 1.4, is drinking water from an improved water source, provided collection time is not more than 30 minutes for a round trip including queuing. "Limited" service is drinking water from an improved source for which collection time exceeds 30 minutes for a round trip including queuing. "Unimproved" is drinking water from unprotected dug well or unprotected spring. "Surface water" is drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal (UNICEF and WHO, 2017). The first three levels of the ladder constitute "improved" water sources. Improved water sources include piped water, boreholes or tube wells, protected dugs wells, protected springs and packaged or delivered water.

development project to construct new boreholes in rural Zambia. To do so, we use detailed time-use survey data to detect any behavioral change in time allocation by access to newly built water facilities. We hope that this study will contribute to better understanding in the literature of the impacts of improved water sources on the community.

Findings from previous literature on the effects of access to safe water on health have not been encouraging. These studies started with the hypothesis that access to safe water may contribute to a reduction in waterborne diseases prevalent in developing countries. However, most studies have reached the conclusion that improved access to water sources does not always have a positive impact on the quality of water used nor on health of the target population (Wright et al., 2004; Zwane and Kremer, 2007; Waddington and Snilstveit, 2009; Kremer et al., 2011).

Instead, most studies have found that improvement of water quality at point of use (POU) is generally more effective in reducing waterborne diseases than other interventions (Gundry et al., 2004; Fewtrell et.al., 2005; Arnold and Colford, 2007; Waddington and Snilstveit, 2009; Clasen et al., 2015). However, these two findings are not necessarily contradictory and the combination suggests that access to safe water sources improved the quality of water at the point of collection but not at the point of use. Any deterioration of water quality is attributed to recontamination by mishandling of improved source water (Fewtrell et.al., 2005; Günther and Schipper, 2013) or mixed-use of unknown quality water (Kremer et al., 2011).

Another strand of the literature related to this study is a series of past studies on the time burden of water collection. In rural sub-Saharan Africa, women spend 2–3 hours per day on water collection on average, which corresponds to 25% of their daily working hours (Rosen and Vincent, 1999). Thus, improved access to safe water may save time spent on water collection and the resulting time gains may be more beneficial for women and girls who are primarily responsible for water collection (Ray 2007; Sorenson et al. 2011; Koolwal and van de Walle 2013).

Most studies on sub-Saharan African countries use cross-sectional data from a limited number of villages and show that an estimated 30 to 300 minutes were saved by improved access to water sources (Cairncross and Cliff 1987; Bevan et al. 1989; Blum et al. 1990). More recently, Devoto et al. (2012) examined the impact of private piped water connections to the water main in Morocco's urban areas and found that 27 minutes per day were saved by switching from a public to a private connection. Gross et al. (2018) found that provision of new public water points in rural Benin saved 41 minutes per day for water collection activities on average. These estimates are among the lowest from among previous studies, partly because the households started to collect a larger number of water containers per day.[2][3]

In line with Devoto et al. (2012) and Gross et al. (2018), we utilize longitudinal data collected at a quasi-experimental setting to examine the impact of improved access to safe water on working-age adults resulting from a groundwater development project.

[2] In addition, Graham et al. (2016) measures the water collection burden on those spending more than 30 minutes per day or not. Graham finds that adult females are primarily responsible for collecting water among households in 24 sub-Saharan African countries not including Zambia.

[3] While outside this study's scope, there is some literature on the impact of safe water access on schooling outcomes for children. As water collection burdens can fall heavily on children (WHO 2007; Morrison, Raju, and Sinha 2007; Ray 2007), improved access to water sources may increase time spent on schooling and increase school attendance by reducing waterborne diseases. Koolwal and van de Walle (2013) found a positive correlation between school enrolment and time reduction at water sources in non-African countries. Deveto et al. (2012) found that private connection to the public water system did not have any impact on school completion, intensive margin of schooling, nor time spent on homework but an increase in time saved spent on leisure. Gross et al. (2018) also showed little impact of public water provision on schooling because improved access only resulted in a small time gain.

In this paper, we define working-age adults as those aged 19-59. We focus on the short-run impact of the project since, at one year, the interval between baseline and end-line in our data is short.

We aim to add new insights to previous studies in two ways. First, we examine the impact of access to supremely safe water from boreholes sunk to a depth of up to 60 meters underground on adult outcomes. Before the boreholes were handed over to villagers, the quality of water passed a variety of tests in addition to the amount of Escherichia coli (E.coli). Thus, we exclude the possibility that our results are susceptible to potential contamination at source. To our knowledge, most previous studies did not use multiple tests to confirm completely uncontaminated water. Moreover, the boreholes in the project were communal and supported by soft components, including reorganization of the Village Water, Sanitation and Health Education (V-WASHE) Committee, which is responsible for general and daily operations and maintenance at the village level.

Second, we employ detailed time use survey data to detect any behavioral change uncovered in time allocation for a variety of activities resulting from improved access to safe water. A complete time-use survey is essential to understand comprehensive channels of the impact of improved safe water access on adults. In contrast to previous studies, which rely on information on incidence of engagement and time spent in specific activities, we fully utilize an exhaustive timetable for the whole day from 5 am to 8 pm during weekdays.

This article proceeds as follows. The next section describes the target project we examine in the paper, while Section 3 explains the research design and the data set. Section 4 explains our empirical strategy and Section 5 shows estimation results and discusses the findings, followed by some concluding comments in Section 6.

2. Zambia and the groundwater development project

(1) Zambia and the project site

Zambia is a sub-Saharan African country with a population of 17 million in 2019. The country faces challenges in expanding the water supply coverage, with only 67.7 percent of households having access to improved sources of drinking water in 2015 (Central Statistical Office, 2016), a slight improvement from 62 percent in 2010. Moreover, the regional disparity in safe water access between urban (89.2 percent) and rural areas (51.6 percent) (Central Statistical Office, 2011) is a serious concern.[4] As a result of lack of access to safe water, diarrhea is among the top ten major causes of morbidity in Zambia and, in recent years, a higher incidence has been observed (Ministry of Health, Republic of Zambia, 2014). The national average incidence of diarrhea per thousand population increased from 6.9 percent in 2008 to 8.6 percent in 2012.[5] The government acknowledges that poor access to protected water points and inadequate clean water sources, as well as lower accessibility and under-utilization of chlorine, are responsible for an increase in diarrhea and calls for improvement of home treatment of water at the community level (Ministry of Health, Republic of Zambia, 2014). The hospital case fatality rates for diarrhea slightly decreased from 74 deaths per

[4] An "improved" drinking water source adequately protects the source from outside contamination, particularly faecal matter, by the nature of its construction and when properly used. This includes piped water into a dwelling, piped water to yard/plot, public tap or standpipe, tube well or borehole, protected dug well, protected spring, rainwater and bottled water (Central Statistical Office, 2016).

[5] Diarrhea (non-bloody) incidence is defined as the number of new cases of diarrhea (non-bloody) per 1,000 population over one year.

1,000 admissions in 2010 to 65 deaths in 2012.[6]

The project sites in this study are in the Luapula Province, located in the northern territory of the country with a population of one million (Central Statistical Office, 2011). The province is economically isolated from the rest of the country and suffers from lower access to safe drinking water (Figure 1). The poverty rate was the highest at 80.5 percent among the provinces in 2010 (Central Statistical Office, 2011), increasing to 81.1 percent in 2015, the second-highest among provinces in 2015 (Central Statistical Office, 2016). Despite rich water resources, the proportion of people in the province with access to safe water was among the lowest, at only 28 percent in 2010 but had substantially improved to 52.9 percent in 2015 (Central Statistical Office, 2016).[7] The province is at high risk of waterborne diseases due to untreated and easily contaminated water sources in many rivers, streams, and lakes. Hygiene is also a factor, particularly in the fish markets along the Luapula River (JICA 2014). The incidence of diarrhea in the province declined from 7.2 percent in 2008 to 6.0 percent in 2010 but increased again to 8.3 percent in 2012, slightly below the national average. The hospital case-fatality rates deteriorated from 54 deaths per 1,000 admissions in 2010 to 69 deaths in the same period (Ministry of Health, Republic of Zambia, 2014).

(2) Groundwater development project

JICA (Japan International Cooperation Agency) has implemented several projects to improve access to safe water in the Luapula Province.[8] JICA provided grant aid

[6] Diarrhea (non-bloody) case fatality rate (CFR) is defined as the number of deaths due to diarrhea (non-bloody) per 1,000 admissions of diagnosed diarrhea (non-bloody).
[7] Geographically, more than 40 percent of the Luapula Province area is occupied by lakes and wetland areas including Lake Bangweulu, Lake Mweru and the Luapula River (JICA, 2014) .
[8] The United Nations Children’s Fund (UNICEF), African Development Bank, Water Aid, and Plan

assistance to the government of Zambia for constructing 200 water facilities with hand pumps in all seven administrative districts in Luapula Province (Project for Groundwater Development in Luapula Province Phase 1). The project, comprised of technical cooperation on operation and maintenance of existing water facilities, supplied about 50,000 people with access to safe water.

The target project in this study is the second phase of the grant aid project for groundwater development in Luapula Province (Project for Groundwater Development in Luapula Province Phase 2), which was implemented between June 2011 and May 2013. The project was financed by JICA and conducted in four districts of the province: Nchelenge, Mwense, Mansa, and Milenge. This phase of the project aimed to reduce water-related diseases by improving access to safe and stable water sources.

The project consists of hardware and software components. The hardware component is the construction of borehole water supply facilities with hand pumps. Each facility was designed to provide 30 liters of water for each of 250 people per day and the project was expected to benefit more than 54,000 people in the four districts in total (JICA 2014). The distinct feature of the facility in the project is the depth of the boreholes with the designed average of 63 meters below the surface (the minimum depth is 30 meters) and the quality of water at each borehole was tested to satisfy the national standards of Zambia before each facility was handed over to the residents (JICA 2014).[9] This study is exempt from potential contamination at source, with water

International also constructed water facilities and provided training for persons in charge of operation and maintenance of facilities. Those efforts improved the proportion of the population with access to safe water from 11.1 percent in 2006 to 28.0 percent in 2010 (Central Statistical Office, 2011).

[9] The test of quality of water included examination of electrical conductivity, pH, iron, manganese, fluorine content, and E. coli. The testing was conducted on-site and any suspicious samples were reexamined at the University of Zambia in Lusaka (JICA, 2014). Iron remover was installed at three sites exceeding the reference value, which are not included in our sample.

tests confirming no contamination at the time of completion.

The software components started with the decision on drilling points among the villagers. These points were selected based on the hydrogeological conditions through field reconnaissance and geophysical soundings, but priority was given to the local residents' demands based on population (JICA 2014). Once the drilling points were determined, the Village Water, Sanitation and Health Education (V-WASHE) Committee was (re) organized. The committee is responsible for general and daily operations and maintenance at the village level, including minor repairs, collection of maintenance fees, and communication with the administration or area pump menders (APMs).[10] Moreover, a variety of training programs were provided to stakeholders to improve understanding of health and sanitation through proper hygiene behaviors and to facilitate residents' ownership of the facilities and their commitment to maintenance activities (JICA 2014).[11] These programs offered knowledge and techniques for the operation and maintenance of the facilities, organizational management skills for V-WASHE members and administration officers, and promoted hygiene and sanitation practices for villagers.

3. Research design and data description

The research design in this study was carefully designed, starting with the selection of project sites. First, 320 sites in the three districts (Nchelenge, Mwense and Milenge) were specified by the Government of Zambia. Each specified site was

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[10] APMs were responsible for maintenance and repairs of the facilities that communities cannot handle for a fee (JICA 2014).

[11] The software components also include capacity-building workshops for V-WASHE members and training at the district level for district officers, WASHE facilitators and APMs.

screened through a preparatory survey using seven criteria to consider the feasibility and relevance of the project implementation.[12][13] Among these, 291 sites satisfied the criteria and were identified as candidates. In total, 216 sites were selected as target sites based on their population size. The remaining 75 sites served as alternative replacements when drilling was unsuccessful at the target sites.

The first round (baseline) of community and household surveys was conducted from June to July 2012, with the second round (end-line) carried out between June and August 2013. Both of these were conducted by an independent local consulting firm hired by the JICA Zambia Office. Both surveys were undertaken in the dry season (April to October in Zambia), with bad roads making travel very difficult during the rainy season (JICA 2014).

At the baseline survey, 14 target sites in Milenge district were randomly selected as the treatment group from the list of villages where the project was to be implemented. As a control group, twelve sites where the project was not to be implemented were also selected. Selection was based on examination of demographic and socio-economic conditions of the villages to ensure similar attributes in both groups. The total number of sample sites in Milenge was 26, with an additional 19 target sites and 17 control sites in Mwense district (36 in total), and 17 target sites and 15 control sites in Nchelenge district (32 in total). The total number of sites in the sample was 94.

[12] The Mansa district was excluded from the survey since the facilities in some sites were handed over to the villagers before the baseline survey.
[13] The seven criteria are: (1) demand for safe and stable water supply; (2) accessibility to the site; (3) hydrogeological conditions; (4) availability of existing water supply facilities; (5) overlap with other related projects; (6) possibility of forming a V-WASHE committee; and (7) residents' willingness to pay for the operation and maintenance costs of the facilities (JICA, 2014).

However, since it was difficult to predict success in obtaining water, the project was not able to obtain water from new boreholes at some target sites. A maximum of two drillings were attempted at one site and, if both were unsuccessful, the site was canceled and replaced with an alternative site (JICA 2014). In total, the project constructed 216 facilities at 214 sites, and replaced 31 target sites. In Milenge district, two facilities were constructed at two sites since the number of unsuccessful sites exceeded the number of alternative sites (JICA 2014).[14]

The sites that did not obtain water were regarded as control sites for the end-line survey, while new target sites were converted from control sites if they succeeded in obtaining water from new boreholes. These conversions between the target communities eventually led to a kind of random assignment between control and non-control groups ideally suited to examining the impact of the project. This process resulted in 21 "project sites" with water access and 5 control sites without in Milenge, 25 project sites and 11 control sites in Mwense, and 18 project sites and 14 control sites in Nchelenge.[15]

At the baseline survey, 8 households were randomly selected in each village and 752 households in 94 sites in total were interviewed (Appendix 1). Since 117 households (15.6% of the total households) dropped out from the sample, the total number of the households which were surveyed both at the baseline and end-line surveys was 635 (434 households in the project sites and 201 households in the control sites).[16]

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[14] Those two sites were not included in this study.
[15] Moreover, other donors had unexpectedly constructed water facilities at our control sites at the end-line survey and those interventions potentially cause an under bias in our estimates of the impact.
[16] Appendix 1 reports the decomposition of the number of households by rounds and districts. Households with fewer family members were more likely to move away but this attrition pattern did not significantly differ between project and control sites (JICA 2014).

We make two remarks on the interval of two rounds of the survey. One is that, with only one year, the interval is short. However, this enables us to examine the short-term impact of safe water access on the outcomes. The other is that the new water facilities were constructed between February 2012 and April 2013 and the first villagers were able to use the facilities in October 2012. Thus, villagers living around different sites started to use them at different times, following the completion of construction in each community. The average period for use of new facilities in the project site was therefore 6 months, varying from 2 months to 10 months.

Both rounds of the survey employed both community and household questionnaires covering a wide variety of socio-economic variables of communities, households, and individuals.[17] The same questionnaire was used in both surveys with minor revisions. Both community and household questionnaires confirmed access to existing water sources outside the house. The community questionnaire confirmed the presence of incumbent water sources and their accessibility in the community. The household questionnaire included information on the distance from the household to each water source and practices of fetching water per day from each water source. The enumerators also conducted a simple test of the quality of drinking water stored at each household to examine whether the drinking water contained a significant amount of E.coli.[18] Furthermore, the household questionnaire collected information about episodes of illness/injury, including diarrhea symptoms for each family member.

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[17] The questionnaires were tested twice to validate the contents and revised prior to the baseline survey (JICA 2014).

[18] E. coli is one of the indicators of water quality and the appearance of spots on the test sheet indicated that the drinking water of the household was contaminated. The test results were independently judged by an enumerator and a supervisor and the project manager made a final judgment when they disagreed with results.

One of the distinct features of the questionnaire was the time use survey. The survey collected exhaustive information on time allocation and asked respondents to fill in a timetable for a whole day by 18 types of activities from 5 am to 8 pm during weekdays.[19] The time use survey allowed us to measure time spent on a variety of activities, including time spent on water collection. It also provided a means of comprehensively understanding the impact of improved access to safe water sources on behavioral change, which is advantageous over a simple question on involvement or time spent on water collection, as frequently used in other studies.

Table 1 reports the means of the proportion of those who had diarrhea in the last 2 weeks among adults aged 19 to 59. Each cell shows the mean incidence of diarrhea symptoms in the project sites and control sites at the baseline survey (2012) and at the end-line survey (2013), respectively. Incidence in the project sites declined from 1.6% at the baseline survey to 1.3% at the end-line survey, while incidence in the control sites increased from 1.2% to 2.1%. The difference-in-differences in the mean is a 1.3% decline in the project sites, though it is not statistically significantly different from zero.

If we divide the sample into females and males, a similar pattern emerges. For females, incidence declined from 2.0% to 1.5% in the project sites, while it increased from 0.9% to 1.4% in the control sites and the difference-in-differences of the mean is a 0.9% decline, which is not statistically significantly different from zero.

For males, the incidence declined from 1.2% to 1.0% in the project sites while it increased from 1.4% to 2.9% in the control sites and the difference-in-differences of the mean is a 1.7% decline, which is larger than females but not statistically significantly

[19] The most knowledgeable person was responsible for providing information on time use but when they were absent, the female spouses were responsible for responding. The 18 activities recorded in the time use survey are presented in Table 3.

different from zero. The simple computation suggests that the improved access to safe water at newly built boreholes may contribute to reducing the incidence of diarrhea symptoms, but the impact is not statistically significantly different from zero. Note that we do not control for any covariates, including individual, household or community characteristics, which are further examined below by using multivariate regression analysis.

Table 2 reports time allocation for female and male adults, separately. The upper part of the table shows time spent on each of 18 activities between 5 am to 8 pm on a weekday by females. The average time spent fetching water in the project sites declined from 1.57 hours at the baseline survey to 0.56 hours at the end-line survey. On the other hand, the average time spent fetching water in the control sites declined from 1.65 hours to 0.72 hours.

There are two reasons for the substantial reduction of time on water collection in both sites. One is that many new water sources were built after the baseline survey, and the other is that the timing of the end-line lagged into August when most villagers started agricultural work. The difference-in-difference in mean is a 0.08 hours decline, which is not significantly different from zero. We observe a similar pattern in time spent on washing/cleaning, cooking, taking care of children/elders, collecting grass and social/community activities; time use declined in absolute terms for both sites, with a larger reduction for the project sites but not significantly different from zero. In contrast, sleeping time reduced in both sites with a larger reduction for the control sites, resulting in a positive difference-in-difference mean that is significantly different from zero.

This is also the case for shopping: the difference-in-difference mean is positive and significant. The average time on other household chores and eating/drinking declined in both sites with a larger reduction for control sites, but the difference-in-difference mean is not significantly different from zero. The average time on income-generating activities increased in both sites with a larger increase for control sites but the difference-in-difference mean is not significantly different from zero. The average time on leisure/relaxing/resting increased substantially by more than an hour in both sites with a larger increase for project sites though not significantly different from zero.

For males, the trend on time spent in each activity is more parallel between project and control sites. The average time spent fetching water time, which is much less than females, decreased in both sites with a larger reduction for project sites though not significantly different from zero. This is also the case for other household chores and social/community activities. The average time on washing/cleaning time, and cooking declined in both sites with a larger reduction for control sites, resulting in a positive difference-in-difference mean that is not significantly different from zero. This pattern is also the case for collecting grass, school and homework, eating/drinking, and sleeping. The average time on income-generating activities decreased in both sites by a similar magnitude, making the difference-in-difference mean not significantly different from zero. The average time on shopping, which is very short, decreased in the project sites but increased in the control sites, resulting in a shorter time in project sites that is significantly different from zero. This result contrasts with those for females. The average time on travel/walking /commuting increased in both sites, but the gap is larger for the control sites, showing a negative in the difference-in-difference mean for the project sites. In other words, the time on those activities declined in the project sites relative to the control sites. Similar to females, the average time on leisure/relaxing/resting increased substantially by an hour in both sites with a larger increase for control sites, but the difference-in-difference mean is not significantly different from zero.

Those observations, though imprecisely estimated, show that the new water facilities constructed by the project seem to slightly decrease time spent on water collection and increase time on shopping and sleeping time significantly for females. On the other hand, the new facilities seem to reduce time spent shopping and travel/walking/commuting significantly for males. The average time spent on leisure/relaxing/resting increased in both sites for both sexes, but the difference-in-difference mean is not significant. Similar to Table 1, the simple difference in difference in mean does not control for any covariates including individual, household and community characteristics, which is further examined below by using multivariate regression analysis.

Table 3 reports the summary statistics of the variable used in the estimation. The sample is confined to households that were surveyed in both rounds. The number of households is 635 in both years and the number of working-age adults aged 19 to 59 is 1310 at the baseline survey and 1283 at the end-line survey. The proportion of females is slightly over half and the average age is 34.4 years old at the baseline survey. The proportion of female-headed households is about 20% and age of head of household exceeds 40 years old. The highest years of schooling among females above 18 is about 5 years, which is lower than for males at about 7 years. The average number of household members is about 5. The proportion of dependent members who are younger than 15 or older than 65 is about 45%. The average amount of durable household assets is approximately 1.4 million Zambian kwacha.[20]

Lastly, the figures on the 2013 survey show information on utilization of the new borehole facilities. The proportion of households in the project sites is 67.6% and 78% of these households in the project sites use the newly built water facilities. In other words, about 80% of the households use the new boreholes while 20% of households do not. Among the borehole users, the average distance to the new boreholes is about two hundred meters from their house, or about a four-minute walk.

4. Empirical strategy

This study employs a difference-in-differences (DID) approach to estimate the impact of the project on adult outcomes. The central assumption for the DID methodology to be valid is the "parallel trend" to postulate that any change between baseline and end-line surveys without the intervention caused by unobserved characteristics is common between the project sites and control sites. In this study, the failure and replacement of the target sites helps to assure the validity of this assumption because they created circumstances similar to a situation where the construction sites had been determined randomly.

In order to confirm whether any observed characteristics are not biased for both sites, we perform a balance test at the baseline before the intervention of the project and compare the variables used in the estimation between the project and control sites. We confirm that there is no significant difference between project and control sites in most variables used in the estimation. Exceptions are the proportion of young children and

[20] 1 US dollar was equal to 5.2 thousand ZMK as of June 2012.

adolescents, the highest years of schooling among females above 18, and agricultural land values. There are slight differences between the project and control sites (Appendix 2). We also need to confirm a balance at village level characteristics between project and control sites. The project sites might have larger populations than the control sites because one of the most important criteria is population, which determines the demand for water, yet we do not see any significant difference in population between project and control sites.[21]

To examine the impact of the project on outcome variables, we use the following specification:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j * t) + \epsilon_{ijt}, \qquad (1)$$

where *i* refers to a household (or individual), *j* points to the site and *t* is time ($t = 0$ for baseline and $t = 1$ for end-line). Y_{ijt} as the dependent variable takes four forms. First, Y_{ijt} is a binary variable to take the value of 1 if an adult had diarrhea in the last two weeks and take the value of 0 otherwise. Second, Y_{ijt} is the number of days missed due to diarrhea symptoms over the last two weeks. Third, Y_{ijt} is a continuous variable of time in hours spent on a variety of activities. Fourth, Y_{ijt} is the log of monthly consumption per capita of household *i*. S_j is a binary variable to take the value of 1 if the site has a successful borehole and 0 otherwise. β_0 to β_3 are the parameters to be estimated. β_3 is the parameter of our interest and measures the impact of the project on the outcomes.

[21] We further confirmed that residents in the project and control sites had similar access to natural resources, such as water and firewood, and that their communities had similar infrastructure conditions, such as roads, irrigation, and electricity, as well as similar access to shops/markets, schools, and health facilities at the time of the baseline survey (Appendix 2).

ϵ_{ijt} is a well-behaved error term. We employ an ordinary least squares (OLS) estimation to obtain the coefficients. When a binary variable is the dependent variable for incidence of diarrhea, our specification is a linear probability model (LPM).

The parallel trend assumption in the DID methodology may be violated if changes in covariates are not common between project and control sites. Thus, we also employ an empirical model with some covariates. The covariates take two forms; X_{ijt} is a vector to include a set of household (individual) characteristics and X_{jt} is a vector containing a set of site *j*'s characteristics other than success of facility construction (S_j). X_{jt} contains dummy variables that capture district-level fixed effects and X_{ijt} contains two dummy variables that capture seasonal differences in the survey months, July or August, reference to June. By adding those covariates, we write another version of our empirical model:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j * t) + X_{ijt}\gamma_1 + X_{jt}\gamma_2 + \epsilon_{ijt}, \quad (2)$$

where the notations are the same as in (1) except γ_1 and γ_2 which are vectors of the parameters to be estimated along with β_s.

We need to be careful to interpret the coefficient β_3 that measures the impact of the project on the outcomes, since not all households in the project sites report that they used new borehole facilities. Thus, these models estimate the intention-to-treat (ITT) impact of the project at the village level to measure the impact of new water facilities in the village. The direct impact of new boreholes by the project is captured by examining the effect on only actual borehole users. Therefore, we also employ the following specifications:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot U_i + \beta_3 \cdot (U_i * t) + \beta_2^e \cdot NU_i + \beta_3^e \cdot (NU_i * t)$$
$$+X_{ijt}\gamma_1 + X_{jt}\gamma_2 + \epsilon_{ijt}, \qquad (3)$$

where the notations are the same except for replacing S_j with U_i and NU_i. U_i is a binary variable to take the value of 1 if the household (individual) used a borehole and 0 otherwise. NU_i is a binary variable to take the value of 1 if the household does not use a borehole at the project site and 0 otherwise. β_3 in Specification (3) captures the direct effect, while β_3^e captures a spillover effect, if any.

Further, we employ the following specification to consider difference in distance from each house to a new borehole facility among borehole users:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot U_i + \beta_3 \cdot (U_i * t) + \beta_4 \cdot (U_i * t * D_i)$$
$$+ \beta_2^e \cdot NU_i + \beta_3^e \cdot (NU_i * t) + X_{ijt}\gamma_1 + X_{jt}\gamma_2 + \epsilon_{ijt}, \qquad (4)$$

where the notations are the same in (3) except D_i which stands for distance to the newly constructed borehole. D_i takes two forms: physical distance in kilometers and time taken in minutes.

All regressions in the following section control for covariates at the individual, household, and village levels, as well as district dummies. All standard errors are clustered at the village level.

5. Estimation results and discussion

Table 4 reports the estimation results on the incidence of diarrhea symptoms over the last two weeks. We focus on the coefficients of interest – the interaction term between project sites (or borehole users) and year dummy to indicate the end-line survey (2013). Column (A), which uses Specification (2), shows that the coefficient is negative and significant, suggesting that the project reduced the incidence of diarrhea by 1.6 percentage points. Column (B), which uses Specification (3), also reports a negative and significant coefficient, suggesting that the incidence of diarrhea declined among working-age adults using the new boreholes by 2.0 percentage points.

Columns (C) and (D) report the estimation results using Specification (4) by adding a new interaction term with distance from house to the borehole. The distance is measured in physical distance in kilometers in Column (C) and time in minutes in Column (D). The coefficients on the interaction terms between borehole users and the end-line year dummy are negative and significant, and the magnitudes are comparable with Column (A) and (B). The coefficients on the interaction terms with distance are insignificant, showing that distance to the borehole has nothing to do with the incidence of diarrhea among working-age adults.

The remaining columns report the results for females and males separately. While the main coefficients are negative for all columns and the magnitudes are comparable with Columns (A) to (D), they are not statistically significant. Thus, we cannot conclude that, although improved access to safe water contributed to the reduction in incidence of diarrhea symptoms for working-age adults, gender difference exists in the realization of health impacts from using the newly built boreholes.

Table 5 extends our estimation to the number of days during which working-age adults were unable to conduct their regular activities due to the diarrheal incidence over the last two weeks. Column (B), which uses Specification (3), reports a negative and significant coefficient, suggesting that the use of the boreholes reduced the number of days missed by 0.08 days. Columns (C) and (D), which use Specification (4), provide similar results, though the coefficient in Column (D) with distance measured in time is insignificant. Columns (E) to (L) explore gender difference, yet none of our parameters of interest is significant, suggesting that the presence of gender difference in health impact is inconclusive.

With these findings, we argue that the impact of the newly constructed boreholes on health outcomes is limited This is in line with most previous literature, which found little impact on the incidence of diarrhea because of recontamination or mixed-use water of unknown quality. Moreover, we argue that the most convincing reason that we detect very small or little impact of the newly constructed borehole on incidence of diarrhea may be because the incidence was very low for adults at 1% to 2 % during the previous 2 weeks (Table 1), even before the project. Thus, we cannot expect that access to safe water dramatically reduces the incidence of diarrhea symptoms.[22] Furthermore, a decline in the number of days missed due to diarrhea constitutes around only 15 percent of the total days missed due to illnesses or injuries.[23] Therefore, the economic benefits resulting from the health impact are also limited.

Table 6 reports the impact of new borehole facilities on time spent fetching water. We focus on the coefficients of interest. Columns (A) and (D) report the negative but

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[22] Shimamura et al. (2020) shows that improved access to safe water reducesincidence of diarrhea for pre-school children whose average incidence is more or less 5% during the previous 2 weeks but not for school age children aged 6 to 18.

[23] The household survey collected information about the number of days during which each individual was unable to perform regular activities due to other illnesses/injuries over the last one month. Among the working-age adults aged 19 to 59, the average number of days missed due to illnesses/injuries including diarrhea was approximately one day over the last one month.

insignificant coefficients, suggesting that the project did not reduce time spent fetching water for female adults. Column (E) to (H) report similar estimation results for male adults. They are also negative but insignificant in all columns, including the additional interaction term in Columns (G) and (H). This shows that time spent on water collection was not affected by the new boreholes for males either.

We argue that there are two opposing forces affecting time spent on water collection. One direction is that, with easier access, households may increase their demand for supremely safe water available at the new boreholes and may make more trips to collect water, as pointed out by Gross et al. (2018). Therefore, improved access to safe water may increase the overall number of trips to collect water and may not contribute to reduce total time on fetching water. The other direction is the shift in the burden of fetching water from adults to children due to easier access to safe water. If this is the case, time spent on water collection by adults decreases, despite the larger volume of water collection. Our estimation results provide inconclusive evidence on the impact of time spent fetching water.

Table 7 reports the impact of new borehole facilities created by the project on time spent on other water-related household chores, such as washing clothes, cleaning dishes, and cooking. For females, the coefficients on the variable of interest are negative and insignificant in all columns (A) to (D), while the coefficients for males in all columns (E) to (H) are positive and insignificant, suggesting that improved access to safe water did not affect time on other water-related household chores.

However, once we restrict our sample to working-age adults living together with pre-school and school-age children, a very critical finding emerges for female adults (Table 8). The coefficients on boreholes users in columns (B), (C), and (D) are negative and significant, indicating that the new boreholes constructed by the project reduced time spent on water-related household chores, including fetching water, by around 0.7 hours among female adults. Shimamura et al. (2020) analyze the same data and find that the construction of the new boreholes increased time on water-related household chores for school-age female children by 0.25 hours. Under an increased demand for safe water in households, the burden of fetching water and other water-related household chores appears to shift from female adults to girls. For males, none of the coefficients on the variable of interest in all columns (E) to (H) are significant, suggesting that time spent on water-related household chores by males was not affected by the project.

Table 9 reports the impact of the project on time spent on income-generating activities. Since it is suggested that female adults spent less time on water-related household chores as a result of the new water facilities, they may use time gain on income-generating activities to enhance household living standards. However, the coefficients on the variable of interest are negative and insignificant in all columns (A) to (D). These results suggest that female adults did not use time gain on income-generating activities. For males, the coefficients on the variable of interest are positive and insignificant in all columns (E) to (H), showing that improved access to safe water did not affect time on income-generating activities for males either.

So far, we confirm that access to safe water at new boreholes reduced time on water-related household chores for female adults, particularly those who live with young girls, but this did not lead to an increase in time spent on income-generating activities. Now, we move to examine changes in time use on activities other than household chores or work. Table 10 reports the impact of new boreholes created by the project on time spent on leisure, relaxing or resting ("leisure" for short below). For females, the coefficient on the variable of interest is positive in all Columns (A) to (D) and the magnitude is large at 0.44 to 0.78. The coefficient in Column (C) is positive and significant, showing that improved access to safe water increased leisure time significantly by 0.78 hours among female adults who live near the newly constructed boreholes. The coefficient on the interaction term with distance is negative and significant in Column (C), suggesting that female adults living physically far from boreholes did not enjoy the same increase in leisure time. For males, the coefficients are generally negative (or small and positive in Column (G)) and insignificant. These results show that time gain from improved access to safe water is now spent on leisure time for female adults and this is not the case for male adults.

Our findings can be summarized as follows. Improved access to safe water at the new boreholes has a significant health impact on reduction in diarrheal incidence but the economic benefits resulting from the health impact are limited for both female and male adults who had low incidence even before the intervention. The new boreholes seem to help reduce time spent on water-related household chores for female adults but did not enhance income-generating activities, while no impact on time allocation for male adults is detected. For females, particularly those who live near the boreholes, time gain from improved access to safe water is spent on leisure. Therefore, the improved access to safe water sources is welfare-enhancing in terms of increasing leisure time for females but is not linked to improved income.

This is confirmed by the impact of new borehole facilities on household consumption. Table 11 reports the estimation results of new water facilities on household consumption per capita as a proxy for income. The coefficients on the variable of interest are not significant in all columns, showing that new borehole facilities did not improve household material living standards. Moreover, the increase in leisure for female adults builds on the shift of water-related household chores onto girls. This sacrifice of girls' time use is clearly not positive.

6. Conclusion

This paper examines the short term impact of improved access to supremely safe water at newly built boreholes on adult health and time allocation in rural Zambia. We observe a significant effect of improved access to safe water on reduction of diarrheal incidence for working-age adults and a resulting decrease in the number of days during which they could not perform their regular activities due to diarrhea. However, because of very low incidence of diarrhea symptoms even before the intervention, the magnitude of its health and economic impact is small. With respect to time allocation, we find that improved access to safe water reduced time spent on water-related household chores, including fetching water for female adults who live together with young girls, suggesting that the burden of water-related household chores shifted from female adults onto girls. We do not observe any significant increase in time spent on income-generating activities. The time gain beneficial for working-age females can be found in leisure time, particularly among those who live near the new boreholes. There is little impact of new water facilities on male outcomes.

Future research should investigate the longer-term effects of improved access to safe water on working-age adults. We could not find any significant impact on consumption expenditure per capita in the short-run. The marginal impact can accumulate in the longer-run and larger impacts may materialize as a consequence of continuous use of safe water for a longer time period.

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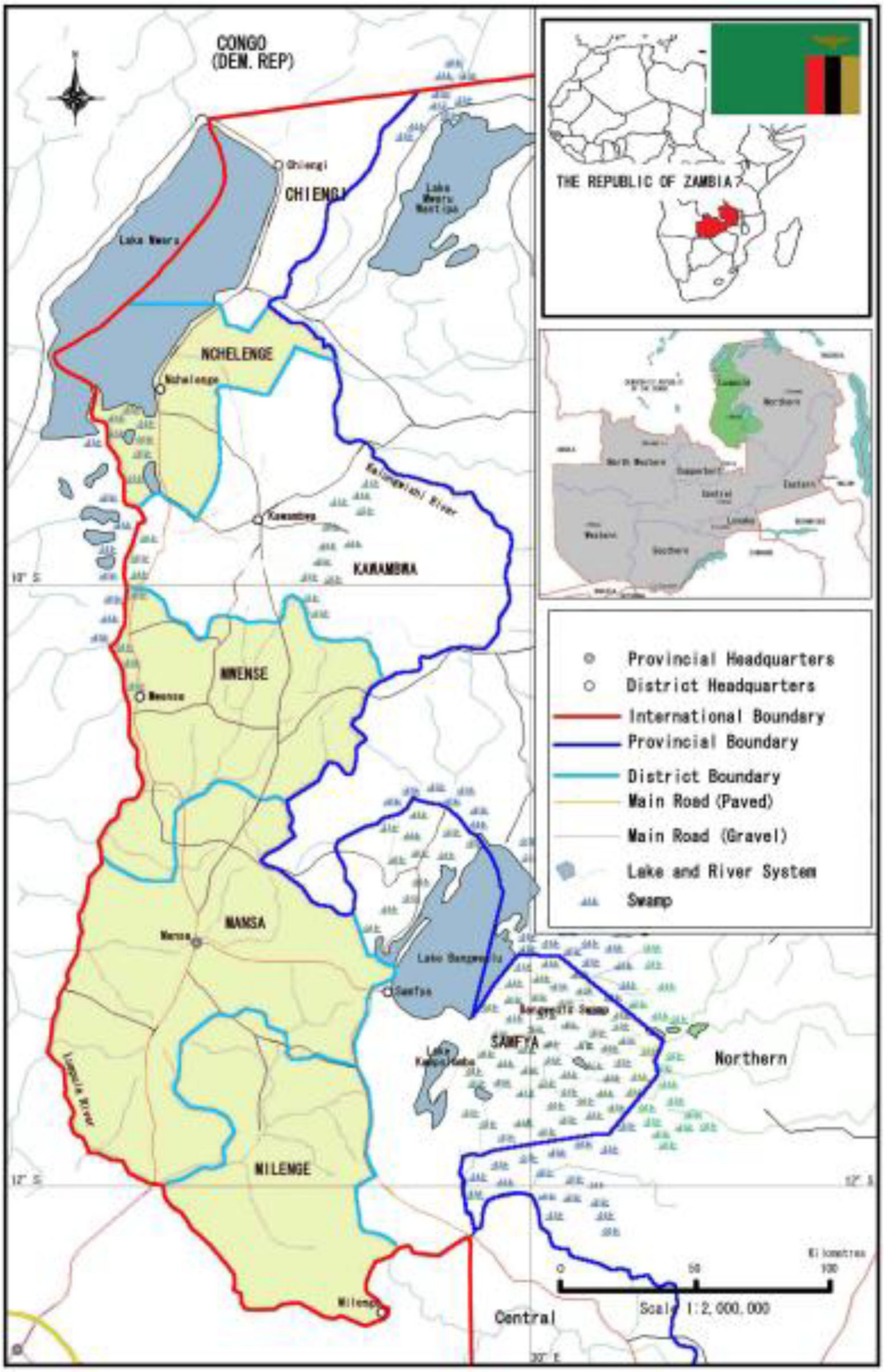
Figure 1 Map of Luapula province



Source: JICA (2014)

Table 1 Incidence of diarrhea symptoms (working-age adults aged 19 to 59)

	Before (2012)		After (2013)		Diff.
	(A)	(B)	(C)	(D)	(E)
	Obs.	Mean	Obs.	Mean	Mean
Incidence of diarrhea symptoms among working-age adults aged 19 to 59					
Project sites	881	0.016	862	0.013	-0.003
Control sites	429	0.012	421	0.021	0.010
Difference-in-Differences					-0.013
Incidence of diarrhea symptoms among working-age female adults aged 19 to 59					
Project sites	459	0.020	453	0.015	-0.004
Control sites	217	0.009	213	0.014	0.005
Difference-in-Differences					-0.009
Incidence of diarrhea symptoms among working-age male adults aged 19 to 59					
Project sites	422	0.012	409	0.010	-0.002
Control sites	212	0.014	208	0.029	0.015
Difference-in-Differences					-0.017

Note: Incidence of diarrheal symptoms over the last two weeks were reported by the respondents of the sampled households. The sample is confined to children in the households which were surveyed in both rounds.
Statistical tests are performed by using the OLS model; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

Table 2 Time allocation in hours from 5am to 8pm (working-age adults 19 to 59)

	Project sites			***Control sites***			**Diff.-in-Diff.**
	Before	***After***	***Diff.***	***Before***	***After***	***Diff.***	
No. of observations (females)	457	448		217	211		
Fetching water	1.57	0.56	-1.01	1.65	0.72	-0.93	-0.08
Collecting firewood	0.17	0.03	-0.14	0.17	0.01	-0.16	0.02
Grazing/taking care of animals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Washing/cleaning	0.65	0.48	-0.17	0.64	0.55	-0.08	-0.09
Cooking	0.97	0.82	-0.15	1.00	0.86	-0.14	-0.01
Taking care of children/elders	0.27	0.11	-0.16	0.21	0.20	-0.02	-0.14
Shopping	0.01	0.01	0.00	0.09	0.00	-0.09	0.09**
Collecting grass	0.10	0.03	-0.07	0.08	0.02	-0.06	-0.01
Other household chores	1.35	1.11	-0.24	1.45	1.14	-0.31	0.07
Income generating activities	3.55	4.10	0.56	3.41	4.66	1.25	-0.70
School and homework	0.39	0.38	-0.01	0.32	0.37	0.05	-0.06
Travel/walking/commuting	0.33	0.49	0.16	0.20	0.47	0.27	-0.11
Social/community activities	0.37	0.20	-0.17	0.22	0.12	-0.10	-0.07
Religious activities	0.12	0.21	0.09	0.07	0.03	-0.05	0.13
Eating/drinking	1.23	0.98	-0.25	1.34	0.95	-0.39	0.14
Leisure/relaxing/resting	1.57	3.10	1.53	1.77	2.88	1.11	0.41
Sleeping	1.33	1.23	-0.10	1.40	1.09	-0.32	0.22*
Other	1.02	1.15	0.13	0.99	0.94	-0.05	0.18
No. of observations (males)	420	407		208	202		
Fetching water	0.34	0.13	-0.21	0.24	0.13	-0.11	-0.10
Collecting firewood	0.25	0.06	-0.19	0.24	0.05	-0.19	0.00
Grazing/taking care of animals	0.00	0.04	0.04	0.00	0.00	0.00	0.03
Washing/cleaning	0.34	0.26	-0.08	0.37	0.28	-0.09	0.01
Cooking	0.11	0.06	-0.05	0.12	0.05	-0.06	0.02
Taking care of children/elders	0.09	0.05	-0.04	0.05	0.01	-0.04	0.00
Shopping	0.04	0.03	-0.01	0.03	0.15	0.12	-0.13*
Collecting grass	0.21	0.12	-0.09	0.26	0.02	-0.24	0.15
Other household chores	0.42	0.26	-0.16	0.30	0.24	-0.05	-0.11
Income generating activities	5.36	5.23	-0.13	5.86	5.74	-0.12	-0.02
School and homework	0.78	0.66	-0.12	0.79	0.51	-0.27	0.15
Travel/walking/commuting	0.47	0.57	0.11	0.16	0.62	0.47	-0.36**
Social/community activities	0.50	0.39	-0.11	0.51	0.47	-0.04	-0.07
Religious activities	0.06	0.19	0.12	0.06	0.10	0.03	0.09
Eating/drinking	1.17	0.88	-0.29	1.24	0.84	-0.39	0.10
Leisure/relaxing/resting	2.30	3.25	0.94	2.19	3.35	1.15	-0.21
Sleeping	1.36	1.17	-0.19	1.33	1.08	-0.25	0.06
Other	1.19	1.66	0.48	1.25	1.33	0.08	0.40

Note: The sample is confined to children in the households which were surveyed in both rounds. Statistical tests are performed by using the OLS model; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

Table 3 Summary statistics of explanatory variables

2012	Mean	s.d.	Min.	Max.
	(A)	(B)	(C)	(D)
Individual characteristics		n=1310		
Female (=1)	0.516	(0.500)	0	1
Age	34.4	(10.76)	19	59
Education (years)	6.016	(3.022)	0	12
Household characteristics		n=635		
Female-headed household (=1)	0.200	(0.400)	0	1
Age of the head	43.1	(13.62)	18	84
Highest education (years) among females	5.114	(2.929)	0	12
Highest education (years) among males	6.825	(2.823)	0	12
Household size	5.203	(2.365)	1	15
Ratio of dependents to household size	0.452	(0.246)	0	1
Value of durable assets (million ZMK)	1.385	(1.915)	0.005	29.40
Surveyed in June (=1)	0.647	(0.478)	0	1
Surveyed in July (=1)	0.353	(0.478)	0	1
Village characteristics		n=94		
Population	467.3	(524.9)	48	3360
Average assets per household (million ZMK)	6.313	(5.214)	1.448	29.30
2013	**Mean**	**s.d.**	**Min.**	**Max.**
	(A)	(B)	(C)	(D)
Individual characteristics		n=1283		
Female (=1)	0.519	(0.500)	0	1
Age	34.9	(10.90)	19	59
Education (years)	5.879	(3.076)	0	12
Household characteristics		n=635		
Female-headed household (=1)	0.195	(0.397)	0	1
Age of the head	43.9	(13.68)	17	85
Highest education (years) among females	4.973	(2.956)	0	12
Highest education (years) among males	6.715	(2.884)	0	12
Household size	5.409	(2.349)	1	15
Ratio of dependents to household size	0.452	(0.234)	0	1
Value of durable assets (million ZMK)	1.767	(3.009)	0.005	47.39
Project site (=1)	0.676	(0.469)	0	1
Project site * Borehole user (=1)	0.526	(0.500)	0	1
Distance to the new borehole (km) [a)]	0.206	(0.213)	0	1
Walking time to the new borehole (min) [a)]	4.072	(5.752)	0	60
Surveyed in June (=1)	0.824	(0.381)	0	1
Surveyed in August (=1)	0.000	0.000	0	0
Village characteristics		n=94		
Population	482.5	(488.0)	80	3360
Average assets per household (million ZMK)	8.074	(6.847)	1.676	55.06

Note: The sample is confined to children in the households which were surveyed in both rounds. Monthly consumption per capita is adjusted by using adult equivalence scales and measured in real terms at the price level of 2012. Assets per household include the value of residence, residential and agricultural land, and durable assets. 1USD was approximately 5200ZMK as of June 2012.

a) The figures are calculated based on the information for only borehole users (n=334).

Table 4 Incidence of diarrhea symptoms over the previous two weeks (working-age adults aged 19 to 59)

Dependent variable: Diarrhea incidence (=1)	All adults aged 19 to 59				Female adults aged 19 to 59				Male adults aged 19 to 59			
	Project	Borehole use			Projec	Borehole use			Project	Borehole use		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
Project and year dummy variables												
Project site/Borehole use	-0.016*	-0.020**	-0.018*	-0.017*	-0.013	-0.020	-0.020	-0.017	-0.019	-0.018	-0.014	-0.016
* Year 2013 (=1)	(0.009)	(0.010)	(0.010)	(0.010)	(0.014)	(0.015)	(0.016)	(0.015)	(0.013)	(0.013)	(0.014)	(0.014)
Project site * Borehole use			-0.009	-0.001			-0.000	-0.001			-0.019	-0.001
* Year 2013 * Distance			(0.022)	(0.000)			(0.037)	(0.000)			(0.019)	(0.000)
Project site/Borehole use (=1)	0.006	0.009	0.009	0.009	0.012	0.018*	0.018*	0.018*	0.000	-0.001	-0.001	-0.001
	(0.006)	(0.007)	(0.007)	(0.007)	(0.009)	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
Project site * Borehole non-		-0.004	-0.004	-0.004		0.011	0.011	0.011		-0.020	-0.020	-0.020
* Year 2013 (=1)		(0.012)	(0.012)	(0.012)		(0.016)	(0.016)	(0.016)		(0.018)	(0.018)	(0.018)
Project site * Borehole non-		-0.003	-0.003	-0.003		-0.008	-0.008	-0.008		0.003	0.003	0.003
		(0.007)	(0.007)	(0.007)		(0.008)	(0.008)	(0.008)		(0.013)	(0.013)	(0.013)
Year 2013 (=1)	0.012	0.012	0.012	0.012	0.010	0.010	0.010	0.010	0.015	0.015	0.015	0.015
	(0.008)	(0.008)	(0.008)	(0.008)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.017	0.018	0.018	0.018	0.025	0.027	0.027	0.028	0.030	0.030	0.030	0.030
No. of observations	2593	2593	2593	2593	1342	1342	1342	1342	1251	1251	1251	1251

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
Distance is measured in kilometers in Columns (C) (G) and (K) and measured in minutes in Columns (D) (H) and (L).

Table 5 Impact on days missed[a)] due to diarrhea symptoms over the previous two weeks (working-age adults aged 19 to 59)

Dependent variable: Days missed (days)	**All adults aged 19 to 59**				**Female adults aged 19 to 59**				**Male adults aged 19 to 59**			
	Project	**Borehole use**			**Project**	**Borehole use**			**Project**	**Borehole use**		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
Project and year dummy variables												
Project site/Borehole use	-0.064	-0.081*	-0.086*	-0.077	-0.046	-0.063	-0.074	-0.060	-0.082	-0.096	-0.093	-0.089
* Year 2013 (=1)	(0.041)	(0.046)	(0.046)	(0.047)	(0.052)	(0.055)	(0.056)	(0.056)	(0.076)	(0.088)	(0.086)	(0.088)
Project site * Borehole use			0.027	-0.001			0.052	-0.001			-0.013	-0.002
* Year 2013 * Distance			(0.083)	(0.001)			(0.138)	(0.001)			(0.077)	(0.002)
Project site/Borehole use (=1)	0.037	0.055	0.055	0.055	0.027	0.047	0.047	0.047	0.053	0.067	0.067	0.067
	(0.037)	(0.042)	(0.042)	(0.042)	(0.037)	(0.042)	(0.042)	(0.042)	(0.071)	(0.083)	(0.083)	(0.083)
Project site * Borehole non-use		-0.010	-0.010	-0.010		0.010	0.010	0.010		-0.041	-0.041	-0.041
* Year 2013 (=1)		(0.039)	(0.039)	(0.039)		(0.054)	(0.054)	(0.054)		(0.067)	(0.067)	(0.067)
Project site * Borehole non-use		-0.021	-0.021	-0.021		-0.037	-0.037	-0.037		0.008	0.008	0.008
		(0.028)	(0.028)	(0.028)		(0.030)	(0.030)	(0.030)		(0.052)	(0.052)	(0.052)
Year 2013 (=1)	0.006	0.006	0.005	0.006	0.020	0.019	0.019	0.019	-0.004	-0.004	-0.004	-0.004
	(0.030)	(0.030)	(0.030)	(0.030)	(0.048)	(0.048)	(0.048)	(0.048)	(0.054)	(0.054)	(0.054)	(0.054)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.013	0.014	0.014	0.014	0.019	0.021	0.021	0.021	0.019	0.020	0.020	0.020
No. of observations	2593	2593	2593	2593	1342	1342	1342	1342	1251	1251	1251	1251

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
Distance is measured in kilometers in Columns (C) (G) and (K) and measured in minutes in Columns (D) (H) and (L).
a) Days missed is defined as the number of days during which working-age adults were unable perform regular activities over the previous two weeks.

Table 6 Impact on time spent fetching water (working-age adults aged 19 to 59)

Dependent variable: Time allocation (hours)	Female adults aged 19 to 59				Male adults aged 19 to 59			
	Project	Borehole use			Project	Borehole use		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Project and year dummy variables								
Project site/Borehole use	-0.130	-0.159	-0.161	-0.161	-0.101	-0.057	-0.027	-0.040
* Year 2013 (=1)	(0.176)	(0.189)	(0.202)	(0.192)	(0.069)	(0.075)	(0.077)	(0.077)
Project site * Borehole use			0.010	0.000			-0.143*	-0.004
* Year 2013 * Distance (km/min.)			(0.220)	(0.007)			(0.084)	(0.003)
Project site/Borehole use (=1)	-0.074	-0.041	-0.041	-0.041	0.106*	0.081	0.081	0.081
	(0.176)	(0.184)	(0.184)	(0.184)	(0.061)	(0.066)	(0.066)	(0.066)
Project site * Borehole non-use		-0.034	-0.033	-0.033		-0.235*	-0.236*	-0.236*
* Year 2013 (=1)		(0.208)	(0.208)	(0.208)		(0.128)	(0.128)	(0.128)
Project site * Borehole non-use		-0.185	-0.185	-0.185		0.181	0.180	0.180
		(0.203)	(0.203)	(0.203)		(0.117)	(0.117)	(0.117)
Year 2013 (=1)	-	-	-	-	-0.104*	-0.104*	-0.103*	-0.103*
	(0.149)	(0.150)	(0.150)	(0.150)	(0.054)	(0.054)	(0.054)	(0.054)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.182	0.183	0.183	0.183	0.151	0.153	0.154	0.154
No. of observations	1333	1333	1333	1333	1237	1237	1237	1237

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%. Distance is measured in kilometers in Columns (C) and (G) and measured in minutes in Columns (D) and (H).

Table 7 Impact on time spent washing/cleaning/cooking (working-age adults aged 19 to 59)

Dependent variable: Time allocation (hours)	**Female adults aged 19 to 59**				**Male adults aged 19 to 59**			
	Project	**Borehole use**			**Project**	**Borehole use**		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Project and year dummy variables								
Project site/Borehole use	-0.138	-0.209	-0.225	-0.292	0.063	0.027	0.029	0.023
* Year 2013 (=1)	(0.174)	(0.181)	(0.188)	(0.182)	(0.084)	(0.091)	(0.093)	(0.093)
Project site * Borehole use			0.070	0.019*			-0.008	0.001
* Year 2013 * Distance (km/min.)			(0.273)	(0.011)			(0.143)	(0.005)
Project site/Borehole use (=1)	-0.023	-0.005	-0.005	-0.004	-0.065	-0.074	-0.074	-0.074
	(0.138)	(0.145)	(0.145)	(0.145)	(0.077)	(0.077)	(0.077)	(0.077)
Project site * Borehole non-use		0.093	0.093	0.095		0.174	0.174	0.174
* Year 2013 (=1)		(0.247)	(0.247)	(0.247)		(0.125)	(0.125)	(0.125)
Project site * Borehole non-use		-0.087	-0.087	-0.086		-0.034	-0.034	-0.033
		(0.180)	(0.180)	(0.180)		(0.120)	(0.120)	(0.120)
Year 2013 (=1)	-0.191	-0.190	-0.191	-0.192	-0.133**	-0.132**	-0.132**	-0.132**
	(0.170)	(0.170)	(0.170)	(0.170)	(0.066)	(0.065)	(0.066)	(0.066)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.106	0.106	0.106	0.106	0.065	0.065	0.065	0.065
No. of observations	1333	1333	1333	1333	1237	1237	1237	1237

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%. Distance is measured in kilometers in Columns (C) and (G) and measured in minutes in Columns (D) and (H).

Table 8 Impact on time spent on water-related household chores [a)] (working-age adults 19 to 59 living with children 3 to 18) [b)]

Dependent variable: Time allocation (hours)	**Female adults aged 19 to 59**				**Male adults aged 19 to 59**			
	Project	**Borehole use**			**Project**	**Borehole use**		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Project and year dummy variables								
Project site/Borehole use	-0.418	-0.622**	-0.693*	-0.744**	-0.086	-0.048	0.001	-0.035
* Year 2013 (=1)	(0.279)	(0.307)	(0.350)	(0.323)	(0.121)	(0.125)	(0.136)	(0.125)
Project site * Borehole use			0.309	0.026*			-0.251	-0.004
* Year 2013 * Distance (km/min.)			(0.472)	(0.015)			(0.284)	(0.007)
Project site/Borehole use (=1)	0.156	0.323	0.325	0.326	0.067	0.021	0.020	0.020
	(0.243)	(0.258)	(0.259)	(0.258)	(0.123)	(0.124)	(0.124)	(0.124)
Project site * Borehole non-use		0.166	0.166	0.167		-0.189	-0.189	-0.190
* Year 2013 (=1)		(0.389)	(0.389)	(0.390)		(0.245)	(0.245)	(0.245)
Project site * Borehole non-use		-0.314	-0.312	-0.310		0.217	0.215	0.216
		(0.310)	(0.310)	(0.311)		(0.231)	(0.232)	(0.232)
Year 2013 (=1)	-	-	-	-	-0.191**	-0.189**	-0.188**	-0.189**
	(0.251)	(0.252)	(0.252)	(0.251)	(0.091)	(0.091)	(0.091)	(0.091)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.215	0.222	0.222	0.224	0.176	0.179	0.179	0.179
No. of observations	840	840	840	840	791	791	791	791

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%. Distance is measured in kilometers in Columns (C) and (G) and measured in minutes in Columns (D) and (H).

a) Water-related household chores comprise fetching water, washing, cleaning, and cooking.

b) The sample is confined to working-age adults aged 19 to 59 who live together with children of the same gender aged 3 to 18.

Table 9 Impact on time spent on income generating activities (working-age adults aged 19 to 59)

Dependent variable: Time allocation (hours)	Female adults aged 19 to 59				Male adults aged 19 to 59			
	Project	Borehole use			Project	Borehole use		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Project and year dummy variables								
Project site/Borehole use	-0.513	-0.379	-0.642	-0.239	0.032	0.056	0.194	0.283
* Year 2013 (=1)	(0.541)	(0.553)	(0.578)	(0.558)	(0.618)	(0.648)	(0.691)	(0.672)
Project site * Borehole use			1.189	-0.033			-0.675	-0.060
* Year 2013 * Distance (km/min.)			(0.902)	(0.029)			(1.026)	(0.043)
Project site/Borehole use (=1)	0.340	0.394	0.394	0.393	-0.414	-0.337	-0.337	-0.342
	(0.342)	(0.353)	(0.353)	(0.353)	(0.401)	(0.404)	(0.404)	(0.404)
Project site * Borehole non-use		-0.941	-0.936	-0.944		-0.044	-0.046	-0.048
* Year 2013 (=1)		(0.762)	(0.762)	(0.762)		(0.786)	(0.787)	(0.787)
Project site * Borehole non-use		0.166	0.169	0.165		-0.660	-0.662	-0.666
		(0.450)	(0.450)	(0.450)		(0.537)	(0.537)	(0.536)
Year 2013 (=1)	0.789*	0.783*	0.773*	0.785*	-0.434	-0.438	-0.432	-0.429
	(0.460)	(0.460)	(0.461)	(0.460)	(0.532)	(0.534)	(0.534)	(0.534)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.099	0.101	0.103	0.102	0.139	0.140	0.140	0.141
No. of observations	1333	1333	1333	1333	1237	1237	1237	1237

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%. Distance is measured in kilometers in Columns (C) and (G) and measured in minutes in Columns (D) and (H).

Table 10 Impact on time spent on leisure/relaxing/resting (working-age adults aged 19 to 59)

Dependent variable: Time allocation (hours)	Female adults aged 19 to 59				Male adults aged 19 to 59			
	Project	Borehole use			Project	Borehole use		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Project and year dummy variables								
Project site/Borehole use	0.436	0.481	0.778*	0.517	-0.265	-0.260	0.036	-0.183
* Year 2013 (=1)	(0.373)	(0.384)	(0.398)	(0.395)	(0.397)	(0.399)	(0.438)	(0.438)
Project site * Borehole use			-1.340**	-0.008			-1.441**	-0.020
* Year 2013 * Distance (km/min.)			(0.660)	(0.034)			(0.678)	(0.033)
Project site/Borehole use (=1)	-0.087	-0.125	-0.125	-0.125	0.131	0.097	0.097	0.096
	(0.204)	(0.211)	(0.210)	(0.211)	(0.259)	(0.270)	(0.270)	(0.271)
Project site * Borehole non-use		0.286	0.280	0.285		-0.281	-0.286	-0.282
* Year 2013 (=1)		(0.529)	(0.529)	(0.529)		(0.593)	(0.592)	(0.593)
Project site * Borehole non-use		0.038	0.036	0.038		0.238	0.233	0.235
		(0.260)	(0.260)	(0.260)		(0.340)	(0.340)	(0.341)
Year 2013 (=1)	1.054***	1.054***	1.065***	1.055***	1.042***	1.043***	1.056***	1.046***
	(0.336)	(0.336)	(0.335)	(0.336)	(0.354)	(0.355)	(0.353)	(0.354)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.130	0.130	0.133	0.130	0.069	0.069	0.072	0.069
No. of observations	1333	1333	1333	1333	1237	1237	1237	1237

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%. Distance is measured in kilometers in Columns (C) and (G) and measured in minutes in Columns (D) and (H).

Table 11 Impact on household consumption expenditure per capita

Dependent variable: log (monthly consumption per capita)	All households			
	Project	Borehole use		
	(A)	(B)	(C)	(D)
Project and year dummy variables				
Project site/Borehole use	-0.066	-0.093	-0.065	-0.089
* Year 2013 (=1)	(0.112)	(0.115)	(0.133)	(0.121)
Project site * Borehole use			-0.133	-0.001
* Year 2013 * Distance (km/min.)			(0.255)	(0.008)
Project site/Borehole use (=1)	0.048	0.064	0.065	0.064
	(0.067)	(0.071)	(0.071)	(0.071)
Project site * Borehole non-use		0.027	0.027	0.027
* Year 2013 (=1)		(0.160)	(0.160)	(0.161)
Project site * Borehole non-use (=1)		-0.008	-0.008	-0.008
		(0.078)	(0.078)	(0.078)
Year 2013 (=1)	0.013	0.013	0.014	0.013
	(0.088)	(0.088)	(0.088)	(0.088)
Household characteristics	Yes	Yes	Yes	Yes
Village variables	Yes	Yes	Yes	Yes
R sq.	0.206	0.206	0.207	0.206
No. of observations	1270	1270	1270	1270

Note: Village-level cluster-adjusted standard errors are in parentheses; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
Distance is measured in kilometers in Column (C) and measured in minutes in Column (D).
Monthly consumption per capita is adjusted by using adult equivalence scales and measured in real terms at the price level of 2012.
1USD was approximately 5200ZMK as of June 2012.

Appendix 1 Number of households in each district and survey

	Baseline (2012)			End-line (2013)			Attrition rate (%)
	Project sites	Control sites	All	Project sites	Control sites	All	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Milenge	168	40	208	150	35	185	11.1
Mwense	192	96	288	151	85	236	18.1
Nchelenge	144	112	256	128	86	214	16.4
	504	248	752	429	206	635	15.6

Appendix 2 Balance test

	Project sites	Control sites	Difference
	(A)	(B)	(C)
Individual characteristics	**n=2239**	**n=1065**	
Female (%)	51.8	50.0	1.9
Age	20.9	20.7	0.2
Aged 0 to 6 (%)	22.8	25.4	-2.7*
Aged 7 to 18 (%)	34.1	30.9	3.2**
Aged 19 to 59 (%)	39.3	40.3	-0.9
Aged 60 and above (%)	3.8	3.4	0.4
Working age females aged 19 to 59	**n=459**	**n=217**	
Education (years of schooling) completed	5.483	4.764	0.719***
Crop farmers (%)	79.5	77.4	2.1
Fishery workers (%)	0.0	0.5	-0.5
Traders/retail shopkeepers (%)	4.8	6.9	-2.1
Working age males aged 19 to 59	**n=422**	**n=212**	
Education (years of schooling) completed	6.895	6.700	0.196
Crop farmers (%)	72.5	71.7	0.8
Fishery workers (%)	4.7	3.3	1.4
Traders/retail shopkeepers (%)	3.1	3.8	-0.7
Household characteristics	**n=429**	**n=206**	
Female-headed household (%)	20.0	19.9	0.14
Age of the head	43.4	42.3	1.18
Household size	5.219	5.170	0.049
Ratio of dependents to household size	0.452	0.453	-0.002
Monthly consumption per capita (thousand ZMK)	162.4	143.2	19.2
Value of durable assets (million ZMK)	1.394	1.366	0.029
Agricultural land value (million ZMK)	3.362	5.138	-1.776*
Village characteristics	**n=63**	**n=31**	
Population (households)	98.2	97.6	0.61
Population (individuals)	480.6	439.8	40.7
Land area (ha)	141.4	98.4	42.9
Flat villages (%)	31.7	38.7	-7.0
Slightly sloping villages (%)	38.1	35.5	2.6
Moderately sloping villages (%)	28.6	22.6	6.0
Steep/hilly villages (%)	1.6	3.2	-1.6
Average assets per household* (million ZMK)	5.940	7.071	-1.131
Distance to district center (km)	45.4	36.4	8.9
Distance to town center (km)	26.5	15.8	10.7
Distance to market (km)	12.3	13.2	-0.9
Distance to government primary school (km)	2.0	2.7	-0.7
Distance to government secondary school (km)	29.2	30.8	-1.6
Distance to rural health center (km)	7.3	9.5	-2.2

Note: t-test or Fisher's exact test results are shown; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
Monthly consumption per capita is adjusted by using adult equivalence scales and measured in real terms at the price level of 2012. Assets per household include the value of residence, residential and agricultural land, and durable assets. 1USD was approximately 5200ZMK as of June 2012.