Tanzanian Economic Review, Vol. 7 Nos. 1 & 2, 2017: 1–18

Assessing the Impact of Improved Water Supply on Health Outcomes in Rural Tanzania

Kenneth Mdadila*

Abstract

This paper, using quasi-experimental methods, assesses the impact of access to water from improved sources on health outcomes of rural households in Tanzania. The study employs Propensity Score Matching techniques in estimating the impact. The outcome variable of interest is diarrhoea incidence among children and households, respectively, in rural Tanzania. Results show that health impact due to improved access to water is notable among all household members and limited among children under five years. Access to water from improved sources reduces diarrhoea incidence by 10.2% and 2.6% among rural households and children, respectively, in the treatment communities. The results further show that sanitation and hygiene promotion interventions are not integrated with the provision of water from improved sources. The mean difference between treatment and control communities on sanitation (usage and ownership of latrine) and hygiene (hand-washing behaviours) are not statistically significant up to 10 percent. The study draws the following policy implications: increasing access of water from improved sources should be an integrated process packaged with sanitation and hygiene interventions since the absence of integration reduces health returns of investing in water infrastructure; deliberate interventions are needed to enhance mothers' knowledge about hygiene practises for better outcomes of child health.

1. Introduction

Over 800 million people in developing countries are vulnerable to water-borne diseases due to the lack of access to safe drinking water (WHO & UNICEF, 2017). It is estimated that the lack of access to improved water and basic sanitation accounts to 5% loss of GDP in developing countries (UNESCO, 2009). Child mortality is also linked to poor access to water. Unsafe drinking water is linked to 90% of the diarrhoea epidemic, which contributes to 20% of child mortality in developing countries (Kosek et al., 2003), and a total of 8% of all lost lives in developing countries (Smith et al., 1999).

Access to improved water is important for socioeconomic development in several ways. First, from the social justice point of view, it is a fundamental human right that everybody should have access to clean and safe water. Second, reduced time spent to fetch water due to improved access can improve school attendance and future incomes (World Bank, 2003; Zwane & Kremer, 2007). Third, women can use the saved time from fetching water into income generating activities (Hutton et al., 2006), which will have immediate welfare improvements of households. Fourth, water supplying provides employment to water vendors, especially the youth. Fifth, access to clean water, when linked to proper sanitation and hygiene practices,

*Department of Economics University of Dar es Salaam, Tanzania: mdikenn@yahoo.com.

reduces exposure to water-borne diseases, including diarrhoea, which is a major sources of child mortality in developing countries (Bartram et al., 2005; Black et al., 2003). Attaining this last issue poses a major policy challenge in developing countries (Gundry et al., 2004), including Tanzania.

Studies have attempted to quantify the possible impact of access to improved water on diarrhoea incidences. Much focus has been on the health impacts of piped water infrastructure (see, e.g., Devoto et al., 2012; Gamper-Rabindran et al, 2010; Jalan & Ravallion, 2001; Waddington et al., 2009), and little on community level water infrastructure (Zwane & Kremer, 2007). Similarly, studies for Tanzania have focused mainly on urban water supply, which mainly uses piped water infrastructure (see, MCC, 2018; Rostapshova et al., 2018). Further, these studies for Tanzania have focused only on urban Morogoro and Dar es Salaam. Evidence for rural Tanzania setting is scant. The current study attempts to provide evidence on the impact of community level water supply on diarrhoea incidences in rural Tanzania.

Over the recent years, particularly from 2007, Tanzania has been undertaking massive investments aimed at providing water from improved sources among households in rural areas. Like in many other settings in developing countries, the rural population of Tanzania is dispersed,[1] making the provision of piped water to households a policy challenge due to the implied costs that are beyond the available means. Providing community-level water infrastructure is sought as the optimal solution; and is the current practice in rural Tanzania (URT, 2012). Therefore, most of the water in rural Tanzania is accessed through community water points. This set-up has led to the improvement of access to water from improved sources in rural areas. Currently, 34.5% of the rural population has access to water from improved sources (UNICEF, 2016). Nonetheless, this progress is faced with some challenges. First, there are concerns on the functionality of water points. It is estimated that over 42% of domestic water points (DPs) become non-functional within the first year after construction (World Bank, 2012). Second, it is a common practice for campaigns on water interventions, sanitation and hygiene to be conducted independent from each other (Gundry et al., 2004), something that has shown to yield minimal health benefits (see, e.g., Klasen et al., 2012).

The fundamental policy question that arises out of Tanzania's rural water supply context as described above is: how does access to water from improved sources impact on diarrhoea incidences under the settings where water supply, sanitation and hygiene interventions are independent? This paper seeks to answer this question. The study contributes to the literature on the evidence on how improving community-level water infrastructure in rural settings—which is characterized by limited linkage between water and sanitation interventions—impacts on health outcomes. To estimate the impact, quasi-experimental methods are employed. In particular, the study uses propensity score matching methods on survey data collected under the Rural Water Supply and Sanitation Programme.

[1]People in rural Tanzania tend to live in their farm areas instead of being concentrated in few areas such as village towns/centers.

After this introductory section, the reminder of the paper is structured as follows. Section two briefly reviews both theoretical and empirical evidence on access to water supply and diarrhoea incidences; and extracts their potential link. Section three presents the data used. Section four provides the empirical strategy applied in the study. Section five presents and discusses the key results, before concluding and drawing policy implications in section six.

2. Water Supply and Health Outcomes: Conceptual Issues and Empirical Evidence

Conceptually, improved water supply is linked to a number of social and economic outcomes affecting the welfare of households and communities. A need for understanding the health outcomes of water supply intervention has led to the development of comprehensive frameworks linking water and diarrhoea incidences (Hasan & Gerber 2016; Waddington & Snilstveit 2009; Wolf et al., 2014). The water-diarrhoea incidence framework (as shown in Fig. 1) provides possible specific transmission pathways through which water supply/quality interventions help to curtail water-borne disease risks such as diarrhoea, dysentery, and cholera (Waddington & Snilstveit, 2009). Multifactorial intervention—i.e., adding sanitation and hygiene education intended to alter the behaviour of beneficiary communities or households—is commonly used to realize the greatest potential for water supply/quality interventions.[2]

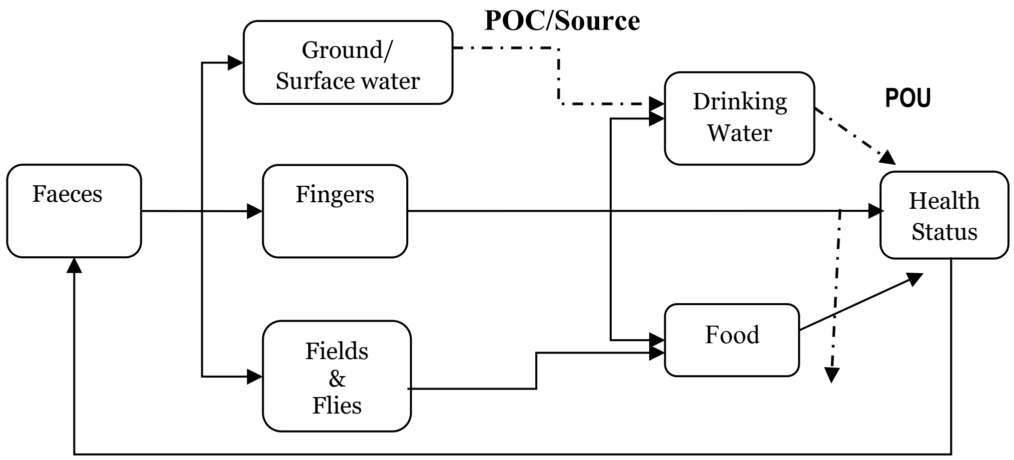

Figure 1: Framework for linking Water and Diarrhoea Incidence

Note: POU denotes Point of Use treatment; and POC denotes Source/Point of Collection treatment.

Source: Pruss et al., (2002) and Waddington et al., (2009).

[2]According to the World Bank (2001), water supply improvements include the provision of an improved source of water and/or improved distribution such as piped water or standpipes, provided either at public (source) or household (point-of-use) levels.

While sanitation interventions aim to break the first-round transmission, water supply and hygiene interventions provide the break of second-round transmission. As argued by Waddington and Snilstveit (2009), water and sanitation interventions collectively counter the diarrhoea incidence by providing the means to protect or treat water by the removal of microbial contaminants at the source or point-of-use (POU) through the use of various treatment technologies such as filtration, chlorination, flocculation, solar disinfection, boiling and pasteurization. All these interventions work to prevent the transmission of pathogens carried from faeces into the body through various mechanisms (fingers, flies, fields, food, and unclean water).

There are vast and ambiguous empirical evidences supporting the causal impacts of access to water on the health outcomes or welfare of households/communities as conceptualized above.[3] Investment in water infrastructure—either through household piped water or community stand-pipe—is thought as a starting point to reduce diarrhoea incidences. Combining such investment with sanitation and hygiene interventions is also deemed as useful in yielding optimal health benefits (Waddington & Snilstveit, 2009; Fewtrell & Colford, 2004; Klasen et al., 2012; Gundry et al., 2004; Taylor et al., 2015; World Bank, 2001). The main argument here is that contamination in water is highly linked to the leakage of water pipe systems and poor hygiene behaviour at the household level.

One hypothesis for the relative ineffectiveness of communal water infrastructure is that a high degree of recontamination of water occurs in transport and storage when people fail to wash their hands frequently (see, Taylor et al., 2015). Thus, there is a general preference of household piped water over communal water infrastructure. However, providing household piped water infrastructure—especially in rural settings of developing countries—appears to be an expensive option (World Bank, 2003; Zwane & Kremer, 2007). As such many developing countries have focused on community-level water infrastructure as an option, on which few studies have been conducted. Most studies have focused on the influence of piped water on health outcomes with varied methods, influenced by the nature of data used. For instance, Kremer et al. (2006, 2009), Luby et al. (2006), Quick et al. (1999), and Zwane and Kremer (2007) have used randomized trials. On the other end, Bose (2009), Hasan and Gerber (2016), Jalan and Ravallion (2001), Klasen et al. (2012), and Begum et al. (2011) have used quasi-experimental methods. There is also a group of regression-based studies (see, Gamper-Rabindran et al, 2010; Lechtenfeld, 2012; Watson, 2006).

Findings from the studies reveal mixed evidences. Waddington and Snilstveit (2009) find that while water treatment interventions have smaller effectiveness, sanitation interventions are highly effective in reducing diarrhoea morbidity. In a meta-analysis of 60 studies, Fewtrell and Colford (2004) found that hygiene education (promoting hand-washing), together with water quality interventions, effectively reduce diarrhoea

---

[3] Health production function framework (e.g., Jalan and Ravallion, 2001) provides alternative conceptual framework. The study focuses on Pruss et al., (2002) and Waddington et al., (2009) framework due to its strength in addressing water and sanitation reinforcement in addressing health outcomes.

risk on the average by about 40% each; while sanitation provision or water supply reduce risk by only around 20% each. Contrary to the study by Waddington and Snilstveit (2009), an analysis by Fewtrell and Colford (2004) showed that water interventions, specifically POU treatment, reduces diarrhoea incidences significantly.

Klasen et al. (2012) reveal that an additional access to sanitation does not show any improvement in reducing diarrhoea incidences in the presence of frequent water rationing. Reliability of water supply combined with good access to sanitation is key to observe health benefits. Klasen et al. (ibid.) estimate that water and sanitation interventions combined reduce diarrhoea incidences from 25% to 37%.

There is no evidence that tracking impact of water on health after much longer time has stronger results since there is a tendency for benefits to disappear over time. Studies have shown that the impacts are visible only around the period of interventions and disappear afterwards. Luby et al. (2006), on the other hand, show that benefits from water supply interventions on disease risks tend to disappear within 18 months after interventions have stopped. There is no clear mechanism on how benefits can be sustained as they appear to be context-specific (Waddington & Snilstveit, 2009). In a study of 1795 villages in India, Jalan and Ravallion (2001) found that access to piped water significantly reduces diarrhoea incidences; and that the prevalence of diarrhoea tends to be high when mothers have low education and household are poor. In a review of 64 papers, Fewtrell et al. (2005) found that all interventions reduce diarrhoea morbidity with pooled risk ratios of 0.98 to 0.51 (1 indicates no effect, while a lower number indicates stronger effects). The study also suggests that water quality interventions, specifically at POU, significantly reduce diarrhoea incidences; but the effect of water supply interventions is relatively higher with the provision of household connections and the use of water separate from household storages.

Zwane and Kremer (2007) point out that environmental, and hygiene (hand-washing), and POU water-treatment interventions minimizes diarrhoea incidences. They found little evidence on the impact of providing community-level rural water infrastructure on diarrhoeal disease risks. Quick et al. (1999), on the other hand, suggest that POU water treatment technologies can reduce diarrhoea incidences by about 20-30%. The study found that children aged between 6 months to 5 years in the intervention area experienced 25% fewer episodes of diarrhoea than those in the comparison area. Kremer et al. (2009) evaluated a spring protection intervention at a sample of 1,200 households in 175 communities, and found that spring protection is very effective in improving the quality of water at the source. Kremer et al. (2006) suggests that water re-contamination during transportation and storage is of less concern. This is consistent with findings by the World Bank (2001) and Begum et al. (2011) who suggested that only combined access—rather than isolated use—of improved water and sanitation can lead to reduced incidences of diarrhoea among children.

As reviewed above, evidences of the health impact of water supply interventions are mixed. While some empirical findings suggest that water supply interventions are substantially effective in reducing diarrhoea incidences (Fewtrell & Colford, 2004), other studies find that such interventions alone are ineffective (Waddington et al., 2009) until when combined with sanitation and hygiene interventions (Gundry et al., 2004; Klasen et al., 2012). Other findings explain that the impacts resulting from interventions last for a short time after interventions end, with no evidence on long-term impacts (Luby et al., 2006); while others hold that water interventions are only effective when applied at POUs (Quick et al., 1999; Zwane & Kremer, 2007), and with guaranteed availability and reliability of water (Klasen et al., 2012).

On their part, Esrey et al. (1988) and Fewtrell and Colford (2004) conclude that safe excreta disposal and proper use of water for personal and domestic hygiene appear to be more important than the quality drinking water in achieving broad health impacts. The current study adds to the literature on the impact of the provision of improved water supply in rural Tanzania under a setting where intervention in improved water provision is independent of sanitation and hygiene interventions. In Tanzania, rural water supply is under the Ministry responsible for water; while sanitation and hygiene are under the Ministry responsible for health. There is no combined package of intervention in water, sanitation and hygiene in Tanzania. Thus, the need to explore how health outcomes respond to such lack of linkages between these policy-intervention components.

3. Data

This paper uses household level data from a survey conducted between August and September 2015.[4] The survey covered randomly selected 2,400 households in 30 systematically sampled local government authorities (LGAs) in Tanzania. Half of the sample comprises households from the treatment communities, and the remaining half or 1,200 households comprises the control group. The treatment group comprises households that receive improved water access from 2011 when massive investment in rural water access was undertaken in the country. Further, communities that received treatment after 2014 were excluded in sample since we consider the time to be too short from the period of data collection to produce credible estimates of the impact. The dataset includes, among others, modules on: access to water and sanitation services; hygiene practices of households; and water test for *E. coli*. Variables from these modules formulate the basis of the current analysis. The sampling of this data was guided by the minimum required sample criteria, where the variable 'boys' enrolment into primary school' required a sample of 2,400 households, which is 240 communities in each 10 households. This was the highest required sample among the outcome variables of interest; and was taken as the sample for the study. The variable for 'diarrhoea incidence' required 1,296 households as a sample, with a statistical power of 80 percent. Thus, the sample size used for the analysis is almost as twice as much as the minimum required sample. The data was collected in non-random settings,[5] creating a challenge of

[4]Data was collected by the African Development Bank (AfDB).

[5]The assignment of households into treatment is driven by demand for water by communities through the O& OD approach, hence it is not random.

establishing credible counterfactual situation (see, Heckman et al., 1998), which required finding a valid control group (Austin, 2011). To establish the counterfactual, the survey applied Heckman et al.'s (1998) suggestions. A balanced design was applied to optimize the statistical power and to ensure self-weighting of the sample. All possible sources of spill-over and contamination effects were accounted for in the sample selection.

A number of variables are used in the analysis. Table 1 provides definitions of the key variables. Consistent with the empirical literature, a set of household characteristics and community pre-intervention characteristics are included in the analysis to control for variations in demographic structure, economic activities, education level, wealth and access to social and economic services. Education, wealth and access to public infrastructure are expected to increase the probability of receiving treatment to improved water supply.

Table 1: Description of the Key Variables Used in the Analysis

Variables	Definition
Diarrhoea (All)	1 if any member of the household experienced diarrhoea two weeks prior to the survey and 0 otherwise
Diarrhoea (Children)	1 if any under-five children experienced diarrhoea two weeks prior to the survey and 0 otherwise
Improved Water	1 if the household had improved water supply and Zero other wise
Treated Drinking Water	1 if the household treated drinking water and 0-otherwise
Own Latrine	1 if households owned a Latrine and 0 otherwise
Use Latrine	1 if households used Latrine and 0 otherwise
Washing Hands (Before eating)	1 if households had tendency of washing hands before eating and 0 otherwise
Washing Hands (Food Preparation)	1 if households had tendency of washing hand before food preparation and 0 otherwise
Washing Hands (After Use Toilet)	1 if households member had tendency of washing their hand after using toilet and 0 otherwise
Age of Household Head	Age of the household's head in years
Male Household Head	1 if the household head was Male and 0 if was female
Household Size	Number of persons living in the household at time of survey
Married	1 if Household head is married and 0 otherwise
Occupation in Agriculture	1 if household participated in Agriculture and 0 otherwise
Education	Highest grade of education completed by Household's head measured by number of years
Mobile Phone Ownership	1 if household owned mobile Phone and 0 if didn't own
Participation in Microfinance	1 if the household located in village with Microfinance and 0-Otherwise
Community had Improved Water	1 if the household located in village with improved water supply and 0-Otherwise
Distance to District Capital (log)	Distance from the Village the household is located to the district capital (in log form)
Agricultural Extension Officer	1 if the household was located in the village with agricultural extension office and 0-otherwise
Central Zone	1 if the household is from Central Zone and 0-Otherwise
Lake Zone	1 if the household is from lake zone and 0-Otherwise
Southern Zone	1 if the household is from Southern Zone and 0-Otherwise

Source: Author's compilation

4. Empirical Strategy

Our main empirical strategy is to estimate and assess the impact of improved access to water on diarrhoea incidences among children and adults in rural Tanzania. Assignment to treatment was driven by the desire to have access to improved water supply as a priority in the community; hence it is not random. In such settings, the utilization of experimental methods such as randomized control trials (RCT) is not feasible. Instead, quasi-experimental methods, including propensity score matching (PSM) and difference-in-differences (DiD), are the appropriate techniques. Also, due to the lack of baseline data and recall information, the study only uses PSM estimator to match treatment and control households from the sample PSM. The measure of interest in this context is the average treatment on treated (ATT).

Rosenbaum (2002) defined propensity score *p(X)* as the conditional probability of receiving treatment given observed characteristics, such that:

$$P(X) = Pr(T = 1/X) = E(T/X) \qquad (1)$$

where $\mathcal{T}$ is the treatment status dummy and X represent set of observed variables.

Given the propensity score *p(X),* the PSM average effect of treatment (ATT), defined as the mean difference in outcome over the common support, is estimated as follows:

$$\widehat{ATT} = E_{P(X)/T=1}\{E[Y(1)/T = 1, P(X)] - E[Y(0)/T1, P(X)]\} \qquad (2)$$

where $Y(1)$ denotes the outcome of treated, and $Y(0)$ stands for the outcome of control group.

To measure the impact, we apply the standard matching procedures. First, we estimate a Probit model of probability of household receiving treatment using a pooled sample of treatment and control groups. To control for observable bias, household and community level time-invariant covariates are included (Rosenbaum, 2002). Further, the choice of covariates ensures that the assumptions of conditional independence (covariates unaffected by receiving intervention) and common support are maintained. Second, we predict the probability of receiving treatment: the propensity scores. To ensure there is no matching bias, we conduct a test for balance of covariates after matching using various PSM estimators. Impact is then estimated and assessed using the best fit PSM estimator. Last, to check for a bias from unobserved characteristics given the inherent weakness of PSM, we conduct the Rosenbaum sensitivity test (Rosenbaum, 2002). Alternatively, approaches such as indigenous switching regression are ideal to address the bias from unobservables. Nonetheless, Rosenbaum test is widely used in community demand-driven interventions, consistent with our set-up.

5. Results

5.1 Descriptive Results

Table 2 shows the descriptive results. Overall, diarrhoea prevalence for adults is 22% in the sampled households; with averages of 17% and 27% for the treatment group and control group, respectively. The difference is statistically at 1%.[6] The difference between treatment and control groups in diarrhoea prevalence for children is much smaller (3.3%), and in favour of the treatment group. Child health in most cases is influenced by other factors; including mother's education and income (Jalan & Ravallion, 2001).

Table 2: Descriptive Statistics of Household and Community Variables before Matching

Variable	Treatment	Control	Total	Difference in Means
Diarrhoea (All)	0.17	0.27	0.22	-0.100***
Diarrhoea (Children)	0.06	0.09	0.08	-0.033**
Improved Water	0.67	0.19	0.44	0.486***
Treated Drinking Water	0.25	0.22	0.23	0.025
Own Latrine	0.89	0.89	0.89	-0.002
Use Latrine	0.92	0.91	0.91	0.007
Washing Hands (Before eating)	0.19	0.18	0.18	0.011
Washing Hands (Food Preparation)	0.11	0.11	0.11	0.000
Washing Hands (After Use Toilet)	0.39	0.37	0.38	0.024
Age of Household Head	46.76	46.45	46.61	0.311
Male Household Head	0.48	0.46	0.47	0.022
Household Size	5.33	5.52	5.42	-0.181
Married	0.80	0.83	0.81	-0.034*
Occupation in Agriculture	0.75	0.84	0.79	-0.083***
Education	6.50	6.15	6.33	0.349*
Mobile Phone Ownership	0.12	0.14	0.13	-0.023
Participation in Microfinance	0.35	0.24	0.29	0.105***
Community had Improved Water	0.17	0.13	0.15	0.032*
Distance to District Capital (log)	3.25	3.21	3.23	0.036
Agricultural Extension Officer	0.33	0.20	0.26	0.130***
Central Zone	0.15	0.18	0.17	-0.029
Lake Zone	0.30	0.29	0.30	0.009
Southern Zone	0.28	0.27	0.27	0.010
Observations	**1,204**	**1,170**	**2,374**	

Note: * p<0.05, ** p<0.01, *** p<0.001

This could explain a small difference observed with respect to the Child Health variable. A notable difference (48.6%) is with respect to access to Improved Water, where 67% of the households in the treatment group have access to Improved Water as compared to only 19% for their counterparties in the control group. Statistically significant mean differences between the two groups are also observed on the variables of Married, Occupation in Agriculture, Education, Participation in Microfinance, Improved Water in Community and availability of Agricultural Extension Officer.

---

[6] Some of these characteristics are used as explanatory variables of the estimated models presented further in this study

As pointed out earlier, interventions in improving water supply in Tanzania are independent of interventions in promoting sanitation and hygiene. Results with respect to the variables on sanitation (Own Latrine and Use Latrine) and hygiene practice (Washing Hands) capture the mismatch. The mean difference for sanitation and hygiene are not statistically significant up to 10% level. Under such a set-up, the returns of providing improved water to the communities are not fully optimized. There is a potential of obtaining more health benefits by using water from improved sources if combined with sanitation and hygiene improvement.

5.2 Regression Results

To obtain the propensity scores we first estimate a Probit model with a binary dependent variable (treatment status), taking a value of 1 if the household received treatment (treatment), and zero if otherwise (control). The estimation of the Probit model in this context is not necessarily guided by economic theory, but much by the treatment design: the focus is on establishing the best fit of the model and predict the credible propensity scores. Table A1 in the Appendix shows the results. Statistically significant results of up to 10% are observed for the variables Occupation in Agriculture, Mobile Phone Ownership, Participation in Microfinance, Agricultural Extension Officer, Central Zone, and Southern Zone. Households that owned mobile phones, with occupation in agriculture, and those from the central and southern zones had less probability to be placed in the program (Treatment). Households that participated in microfinance, as well as those located in communities with agricultural extension offices, had higher probability of receiving treatment.

5.3 Test for Balancing Property

Five different matching approaches were used to evaluate the impact of piped water on health outcomes. The idea was to establish which of the matching estimators provide the minimum bias. Table 3 presents the summary statistics of the balancing tests after estimating propensity score matching.

Table 3: Summary Statistics on Various Balancing Tests after PSM

Estimator	Sample	Ps R2	LR chi2	p>chi2	Mean Bias	Median Bias
Radius	Unmatched	0.036	119.82	0.000	9.7	7.5
	Matched	0.002	5.11	0.984	1.6	1.2
Nearest Five	Unmatched	0.036	119.82	0.000	9.7	7.5
Neighbours	Matched	0.002	6.46	0.953	1.8	1.4
Nearest One Neighbour	Unmatched	0.036	119.82	0.000	9.7	7.5
(with Replacement)	Matched	0.003	9.82	0.775	2.9	2.9
Nearest One Neighbour	Unmatched	0.036	119.82	0.000	9.7	7.5
(with no Replacement)	Matched	0.028	91.68	0.000	8.0	6.7
Kernel	Unmatched	0.036	119.82	0.000	9.7	7.5
	Matched	0.004	12.23	0.588	2.9	1.6

Source: Author's Computation using 2015 AfDB data

The radius estimator shows the least mean bias (1.6) and the least median bias (1.8); as compared to the rest of estimators (see Table 3); and hence it is used in our analysis.

To further check for the matching quality of the radius estimator, we provide detailed Balance Test results in Table A2. A distribution difference in covariates by treatment status leads to differences in the averages of the propensity scores for the treatment and control groups (Rosenbaum, 2002). As Table A2 shows, there are high distribution differences between the treated and control groups before matching (unmatched sample). After performing radius matching, differences in observable characteristics between treated and control households reduced significantly from 9 in the unmatched sample, to only 1 in the matched sample. Only one covariate (distance to district capital) had unbalanced distributions in the matched sample. Thus, the test results of equality of covariates confirm the quality of radius matching; and support the fact that the estimates of ATT provide credible estimates.

5.4 Impact Results

Table 4 presents the impact estimates for individuals in households and for children sub-samples. Each of these estimates were done separately. The estimate of interest is the ATT. The results suggest for a significant effect of the reduction of diarrhoea incidences due to access to water from improved sources. The effect is larger for individuals in households than it is for children. Access to water from improved sources reduced diarrhoea incidence by 10.2% among households in treatment communities. Similarly, it reduced the incidence by 2.6% for children living in the treatment communities. The results are statistically significant at 1% for children and all individuals in households, respectively. Results from the unmatched sample are also reported in the Table 4 for comparison purposes. Generally, they portray similar picture to those of the ATT results. Access to water from improved sources, based on the unmatched sample, reduces diarrhoea incidence by 9.9% for individuals in households, and by 3.3% among children living in communities that received treatment. The established impact quantities are much lower as compared to other typical developing countries, where the benefits or reduction in diarrhoea incidences have ranged between 25% and 37% (Klasen et al., 2012; Fewtrell & Colford, 2004). This has been the case when water intervention goes hand in hand with sanitation and hygiene interventions (ibid).

Table 4: Impact on Health - Diarrhoea Incidence

Variable	Sample	Treated	Controls	Difference	Standard Error (SE)
Diarrhoea (All)	Unmatched	0.168	0.268	-0.099***	0.0168
	ATT	0.168	0.270	-0.102***	0.0180
Diarrhoea (Children)	Unmatched	0.061	0.093	-0.033**	0.0109
	ATT	0.061	0.087	-0.026**	0.0117

Note: S.E. does not take into account that the propensity score is estimated; * p<0.05, ** p<0.01, *** p<0.001.

The findings in Table 4 underscore the inherent rural households' health benefits associated with increasing access to water supply in rural areas such that increasing access to improved water supply can drastically reduce diarrhoea incidences to the people, and children in particular. A plausible explanation is widely mentioned in various literatures: that non-access to improved water supply might be an important factor in explaining diarrhoea incidences. The literature also stresses on the need to link interventions in water supply with interventions in sanitation and hygiene to yield optimal health benefits. It would have been useful to also estimate the impact on sanitation and hygiene. The descriptive results have shown statistically insignificant results on sanitation and hygiene variables. Our attempt to estimate impacts for sanitation and hygiene confirmed the descriptive results: they were not statistically significant at up to 10% level, and hence the results are not reported here.

5.5 Sensitivity Test

PSM rest on the assumption of conditional independence that selection into treatment and outcome variables between treatment and control groups do not differ significantly (Rosenbaum, 2002). The Mantel-Haenszel statistics approach is used to test for bias resulting from unobserved characteristics or variables that affect the selection process (positive or negative bias), either causing an under- or over-estimation of matching results. A negative selection bias happens when those households that are mostly likely to be treated tend to have less diarrhoea incidences even without treatment, and hence underestimate estimated treatment effects (downward bias). A positive selection bias occurs when households with improved water supply have higher diarrhoeal prevalence rate, and hence overstate estimated treatment effects (upward bias). Results from our test fails to establish evidence of bias even beyond a factor of 2 for both households and for the children sub-samples (see Table A3).

6. Conclusion and Policy Implication

Poor access to water from improved sources is linked to diarrhoea incidences, the major cause of child mortality in developing countries, including Tanzania. It becomes more detrimental when poor access to water is coupled with the lack of improved sanitation and poor hygiene practices. Improving water supply, particularly in rural areas, is a policy priority in Tanzania. The government is undertaking huge infrastructural investments to ensure the number of people using water from improved sources increases over time. Evidence produced in this study points to visible health benefits of using water from improved sources among rural households. Nonetheless, the impact found is limited compared to other typical developing countries with similar interventions. Literature suggests that health the benefits of using water from improved sources increase when the use of improved sanitation and hygiene practices are integrated in the process at the household level. The argument is that water contamination can occur at the POU when poorly handled or treated. How effective can these three health inputs (water, sanitation and hygiene) be integrated is a fundamental policy challenge that needs to be addressed.

This study has used data from nationwide rural water supply intervention to quantify the health impact of accessing water from improved sources. The health outcome of interest was diarrhoea incidences among children and households in rural Tanzania. Using PSM methods on data from treatment and control communities, the health impact has been established. The results show a higher diarrhoea incidence reduction effect for households than for children. This is not a surprising finding given that children are more prone to water-borne diseases.

Two policy implications arise from our analysis. First, intervention to increase access of water from improved sources should be an integrated process packaged with sanitation and hygiene promotion interventions. The absence of integration reduces the health returns of investing in water infrastructure. Second, deliberate hygiene interventions are needed to enhance child health outcomes. One of the interventions widely emphasized in the literature is the enhancement of mothers' knowledge about the use of clean water combined with hygiene practises.

References

Austin, P. C. 2011. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. *Multivariate Behavioural Research,* 46(3): 399–424.

Bartram, J., K. L., R. Lenton & A. Wright. 2005. Focusing on Improved Water and Sanitation for Health - Millennium Project. *The Lancet,* 365: 810–12.

Begum, S., M. Ahmed & B. Sen. 2011. Do Water and Sanitation Interventions Reduce Childhood Diarrhoea? New Evidence from Bangladesh. *Bangladesh Development Studies,* 34(3): 1–30.

Black, R. E., S. S. Morris & J. Bryce. 2003. Where and Why Are 10 Million Children Dying Every Year? *Lancet,* 361(9376): 2226–34.

Bose, R. 2009. The Impact of Water Supply and Sanitation Interventions on Child Health : Evidence from DHS Surveys.

Cutler, D. & G. Miller. 2005. The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States. *Demography,* 42 (1): 1-22

Devoto, F., E. Duflo, P. Dupas, W. Pariente & V. Pons. 2012. Happiness on Tap: Piped Water Adoption in Urban Morrocco. *American Economic Journal: Economic Policy* 4(4): 68–99.

Esrey, S. A., J.P. Habicht, M.C. Lathman, D.G. Sisler, & G. Casella. 1988. Drinking Water Source, Diarrhoeal Morbidity & Child Growth in Villages with Both Traditional and Improved Water Supplies in Rural Lesotho, Southern Africa. *American Journal of Public Health,* 78(11): 1451–55.

Fewtrell, L., R.B. Kaufmann, D. Kay, W. Enanoria, L. Haller & M.J. Colford. 2005. Water, Sanitation & Hygiene Interventions to Reduce Diarrhoea in Less Developed Countries: A Systematic Review and Meta-Analysis. *The Lancet. Infectious Diseases,* 5(1): 42–52.

Fewtrell, L. & J. M. Colford. 2004. Water, Sanitation and Hygiene: Interventions and Diarrhoea: A Systematic Review and Meta-Analysis. HNP Discussion Paper. Washington, DC. World Bank

Gamper-Rabindran, S & Khan, Shakeeb & Timmins, Christopher. 2010. The Impact of Piped Water on Infant Mortality Rate in Brazil. A Quantile Panel Data Approach. *Journal of Development Economics*, 92(2): 188–200.

Gundry, S., J. Wright & R. Conroy. 2004. A Systematic Review of the Health Outcomes Related to Household Water Quality in Developing Countries. *Journal of Water and Health,* 2(1): 1–13

Hasan, M. M. & N. Gerber. 2016. The Impacts of Piped Water on Water Quality, Sanitation, Hygiene and Health in Rural Households of North-Western Bangladesh - A Quasi-Experimental Analysis. *SSRN Electronic Journal,* (217).

Heckman, J. J., L. Lochner & C. Taber. 1998. Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents. *Review of Economic Dynamics,* 1(1): 1–58.

Hirano, K., G. Imbiens & R. Geert. 2003. Efficient Estimation of Average Treatment Effects Using the Estimated Propensity Score. *Econometrica,* 71(4): 1161–89.

Hutton, G., E. Rehfuess, F. Tediosi & S. Weiss. 2006. *Evaluation of the Costs and Benefits of Household Energy and Health Intervantions at Global and Regional Levels*. Geneva: World Health Organization

Jalan, J. & M. Ravallion. 2001. *Does Piped Water Reduce Diarrhoea for Children in Rural India?* World Bank Policy Research Working Paper no. WPS 2664. Washington, DC: World Bank.

Klasen, S., T. Lechtenfeld, K. Meier & J. Rieckmann. 2012. Benefits Trickling Away: The Health Impact of Extending Access to Piped Water and Sanitation in Urban Yemen. *Journal of Development Effectiveness,* 4(4): 537–65.

Kosek, M., C. Bern & R. L Guerrant. 2003. The Global Burden of Diarrhoeal Disease as Estimated from Studies Published between 1992 and 2000. *Bull Health Organ* 81(3): 197–204.

Kremer, M., J. Leino, E. Miguel & P.A. Zwane. 2009. Spring Cleaning: Rural Water Impacts, Valuation and Property Rights Institutions. NBER Working Paper No. 15280

Kremer, M., & Leino. J & Miguel, E & Zwane, P. A,. 2006. Spring Cleaning : A Randomized Evaluation of Source Water Quality Improvement. Working Paper

Lechtenfeld, T. 2012. Why Does Piped Water Not Reduce Diarrhoea for Children ? Evidence from Urban Yemen. Poverty, Equity and Growth. Discussion Papers 119, Courant Research Centre PEG.

Luby, S. P., M. Abgoatwalla, J. Painter, A. Altaf, W. Billhimer, B. Keswick & R.M. Hoekstra. 2006. Combining Drinking Water Treatment and Hand Washing for Diarrhoea Prevention, a Cluster Randomised Controlled Trial. *Tropical Medicine and International Health,* 11(4): 479–89.

MCC. 2018. Measuring Interim Results of Tanzania Water Sector Project. Millenium Challenge Corporation. Dar es Salaam

Pruss, A., D. Kay, L. Fewtrell & J. Bartram. 2002. Estimating the Burden of Disease from Water, Sanitation, Hygene at a Global Level. *Environmental Health Perspectives,* 110(5): 537.

Quick, R. E., L.V. Venczel, E.D. Mintz, L. Soleto, J. Aparicio, M. Gironaz, L. Hutwagner, K. Greene, C. Bopp, K. Maloney, D. Chavez, M. Sobsey & R.V. Tauxe. 1999. Diarrhoea Prevention in Bolivia through Point-of-Use Water Treatment and Safe Storage : A Promising New Strategy Stable URL : http://www. jstor. org/stable/3865238 REFERENCES Linked References Are Available on JSTOR for This Article : Diarrhoea Prevention I. 122(1): 83–90.

Rostapshova, O. & Roumis, D. & Duthie, M. & Alwang, J. 2018. Impacts of an Urban Water System Investment on Health, Well-being and Poverty. Social Impact. World Bank

Rosenbaum, P. R. 2002. *Design of Observational Studies.* Springer Series in Statistics. New York.

Taylor, D., T. Kahawita, S. Cairncross & J. Ensink. 2015. The Impact of Water, Sanitation and Hygiene Interventions to Control Cholera: A Systematic Review. *PLoS ONE,* 10(8): 1–19.

United Nations Educational, Scientific and Cultural Organization (UNESCO). 2009. Water in a Changing World. *World Water,* 11(4): 349.

United Nations Children's Fund (UNICEF). 2016. Five Year Development Plan *Water and Sanitation - Budget Brief: Financial Year 2011/2012 - 2015/2016.* UNICEF, Dar es Salaam, Tanzania

Waddington, H. & B. Snilstveit. 2009. Effectiveness and Sustainability of Water, Sanitation & Hygiene Interventions in Combating Diarrhoea. *Journal of Development Effectiveness,* 1(3): 295–335.

Waddington, H., B. Snilstveit, H. White & L. Fewtrell. 2009. *Water , Sanitation and Hygiene Interventions to Combat Childhood Diarrhoea in Developing Countries.* The International Initiative for Impact Evaluation (3IE). New Delhi, India: 3ie.

Watson, T. 2006. Public Health Investments and the Infant Mortality Gap: Evidence from Federal Sanitation Interventions on U.S. Indian Reservations. *Journal of Public Economics,* 90(8–9): 1537–60.

Wolf, J., A. Prüss-Ustün, O. Cumming, J. Bartram, S. Bonjour, S. Cairncross, T. Clasen, M. John, M. J. Colford (Jr), V. Curtis, J. De France, L. Fewtrell, M.C. Freeman, B. Gordon, P.R. Hunter, A. Jeandron, R.B. Johnston, D. Mäusezahl, C. Mathers, M. Neira, & J. P. T. Higgins. 2014. Systematic Review: Assessing the Impact of Drinking Water and Sanitation on Diarrhoeal Disease in Low- and Middle-Income Settings: Systematic Review and Meta-Regression. *Tropical Medicine and International Health* 19(8): 928–42.

World Bank. 2003. *Water, Sanitation, and Hygiene at a Glance.* At: https://openknowledge. worldbank.org/handle/10986/9715 License: CC BY 3.0 IGO.

WHO and UNICEF. 2017. *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines.* Geneva, CC BY-NC-SA 3.0 IGO

Zwane, A. P. & M. Kremer. 2007. What Works in Fighting Diarrhoeal Diseases in Developing Countries? A Critical Review. *World Bank Research Observer,* 22(1): 1–24.

APPENDIX

Table A1: Probit Model on Household Receiving Improved Water

Treatment	
Age of Household Head	0.002
	(0.0019)
Male Household Head	0.065
	(0.0526)
Household Size	-0.014
	(0.0115)
Married	-0.098
	(0.0718)
Occupation in Agriculture	-0.295***
	(0.0687)
Education	0.007
	(0.0068)
Mobile Phone Ownership	-0.176*
	(0.0807)
Participate in Microfinance	0.318***
	(0.0629)
Community had Improved Water	0.026
	(0.0766)
Distance to District Capital (log)	0.047
	(0.0280)
Agriculture Extension Officer	0.387***
	(0.0627)
Central Zone	-0.259**
	(0.0838)
Lake Zone	-0.137
	(0.0740)
Southern Zone	-0.264***
	(0.0784)
Constant	0.065
	(0.1760)
N	2,374
chi2	120.5
p	0.000

Note: Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

Table A2: Test of Equality of Covariates Means after Radius Matching

Variable		Mean Treated	Mean Control	%bias	%reduction	t-test t	t-test p>t	V(T)/V(C)
Age of Household Head	U	46.83	46.45	2.7		0.650	0.515	1.01
	M	46.83	46.91	-0.5	80.4	-0.130	0.900	0.95
Male Household Head	U	0.48	0.46	4.2		1.020	0.306	1.00
	M	0.48	0.48	1	75.4	0.250	0.800	1.00
Household Size	U	5.34	5.52	-7.3		-1.770	0.076	0.98
	M	5.34	5.33	0.1	99.3	0.010	0.990	1.04
Married	U	0.80	0.83	-8.5		-2.060	0.039	1.15*
	M	0.80	0.80	-0.9	88.8	-0.230	0.822	1.01
Occupation in Agriculture	U	0.75	0.84	-20.4		-4.970	0.000	1.35*
	M	0.75	0.77	-3.8	81.5	-0.870	0.383	1.04
Education	U	6.51	6.15	8.7		2.130	0.034	1.14*
	M	6.51	6.54	-0.5	93.8	-0.130	0.897	1.06
Mobile Phone Ownership	U	0.12	0.14	-6.9		-1.670	0.095	0.86*
	M	0.12	0.11	1.9	72.0	0.500	0.620	1.05
Participate in Microfinance	U	0.35	0.24	23.2		5.660	0.000	1.24*
	M	0.35	0.34	1.4	94.0	0.330	0.744	1.01
Community had Improved Water	U	0.17	0.13	9.0		2.200	0.028	1.20*
	M	0.17	0.17	-1.9	78.6	-0.450	0.652	0.97
Distance to District Capital (log)	U	3.25	3.21	3.6		0.860	0.388	1.21*
	M	3.25	3.24	1.0	71.9	0.250	0.806	1.22*
Agriculture Extension Officer	U	0.33	0.20	29.9		7.260	0.000	1.39*
	M	0.33	0.32	1.9	93.5	0.440	0.657	1.01
Central Zone	U	0.15	0.18	-7.8		-1.890	0.059	0.87*
	M	0.15	0.13	5.1	34.1	1.340	0.181	1.12
Lake Zone	U	0.30	0.29	2.1		0.510	0.609	1.02
	M	0.30	0.30	0.5	74.5	0.130	0.896	1.00
Southern Zone	U	0.28	0.27	2.1		0.520	0.604	1.02
	M	0.28	0.27	1.7	22.2	0.410	0.685	1.02

Note: * If variance ratio outside [0.89; 1.12] for U and [0.89; 1.12] for M

Table A3: Sensitivity of the Estimated Impact on Health Due to Unobserved Factors

Gamma	Q_mh+	Q_mh-	p_mh+	p_mh-
		Diarrhoea (All)		
1.00	5.83488	5.83488	2.70E-09	2.70E-09
1.25	8.10134	3.60656	2.20E-16	0.000155
1.50	9.98869	1.80190	0.000000	0.035780
1.75	11.6169	0.28221	0.000000	0.388891
2.00	13.0561	0.93104	0.000000	0.175916
2.25	14.3513	2.09229	0.000000	0.018206
2.50	15.5329	3.13430	0.000000	0.000861
2.75	16.6227	4.08099	0.000000	0.000022
3.00	17.6365	4.94978	0.000000	3.70E-07
		Diarrhoea (Children)		
1.00	2.90676	2.90676	0.001826	0.001826
1.25	4.37424	1.46906	6.10E-06	0.070908
1.50	5.60416	0.30524	1.00E-08	0.380093
1.75	6.67286	0.51833	1.30E-11	0.302115
2.00	7.62446	1.36907	1.20E-14	0.085489
2.25	8.48698	2.12353	0.000000	0.016855
2.50	9.27928	2.80352	0.000000	0.002527
2.75	10.0147	3.42423	0.000000	0.000308
3.00	10.7031	3.99663	0.000000	0.000032

NB: Gamma: odds of differential assignment due to unobserved factors; Q_mh+: Mantel-Haenszel statistic (assumption: overestimation of treatment effect); Q_mh- : Mantel-Haenszel statistic (assumption: underestimation of treatment effect); p_mh+: significance level (assumption: overestimation of treatment effect); p_mh- : significance level (assumption: underestimation of treatment effect)