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Water, sanitation, and hygiene for child health: some evidence in support of public intervention in the Philippines

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As in many developing countries, diarrheal diseases remain a top cause of child mortality and morbidity in the Philippines. Partly to address this problem, the government has undertaken programs to expand or promote access to safe water and sanitation facilities, especially among poor households. To assess the possible impact of such interventions on child health, we apply the propensity score matching technique on the pooled data from the last five rounds of the National Demographic and Health Survey.

We find that improved water and improved sanitation each reduced the probability of child diarrhea in 1993-2008 by around two percentage points. In 2013, improved water reduced the probability by about 7 percentage points. On the other hand, improved sanitation does not seem to have a statistically significant effect. These results lend support to the government's programs to widen access to safe water and sanitation facilities as measures to improve child health.

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1. Introduction

In September 2015, the United Nations adopted a new set of development goals for another fifteen years, continuing with and building on the achievements with the first set. Two targets common in both the 2030 Sustainable Development Goals (SDGs) and the 2015 Millennium Development Goals (MDGs) concern widening

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sustainable access to safe drinking water, improved sanitation, and reducing child mortality. In 2010, the World Health Organization (WHO) and the United Nations Children's Emergency Fund (UNICEF) reported mixed prospects regarding the attainment by 2015 of the MDG of reducing by half the proportion of population without access to sources of safe drinking water and basic sanitation facilities, hence the need to include the same in the 2030 MDGs. While the sustainable access to improved water sources and sanitation facilities is a worthy end in itself, achieving this goal may also help accomplish the SDG target of reducing child mortality, which in many developing countries is due to diarrheal diseases.

According to the WHO[2], globally, diarrheal disease accounts for about 760,000 deaths in children under five, making it the second leading cause of child mortality. Diarrhea, also a leading cause of malnutrition in young children, then indirectly weakens their immune system and increases their risk of falling ill. In the WHO's Western Pacific Region, diarrheal diseases account for 8 percent of deaths in under-5 children in 2000 and 6 percent in 2013, in both years accounting for more child deaths than HIV/IDS, measles, and malaria combined [WHO 2015]. Averting some of these deaths simply requires breaking the fecal-oral transmission of bacteria and other microbial pathogens that cause diarrheal diseases. An effective way to achieve this is through the water, sanitation, and hygiene interventions: access to safe drinking water and sanitation facilities and better hygiene practices (WHO and UNICEF [2010]; Prüss et al. [2002]).

Thus, the developing countries that invest in water, sanitation, and hygiene interventions are deemed to have taken a crucial step in improving the health outcomes of children. The impact evaluation of such public investments, however, is constrained by inadequate information not only on coverage, quality, and cost-effectiveness of various possible water and sanitation programs, but also on the actual hygiene practices of the target population. Although recent systemic reviews and meta-analyses affirm the effectiveness of water, sanitation, and hygiene interventions in general, these studies also report that the different types of interventions vary in effectiveness (Gundry, Wright and Conroy [2004]; Clasen et al. [2007]; Waddington et al. [2009]; Clasen et al. [2010]). For example, piped water may not always be effective in reducing diarrheal diseases because water quality deteriorates from the point of source to the point of use due to leaky pipes or contaminated storage. While some households attempt to mitigate the effects of contaminated water, their hand washing and water treatment practices are found to have varying impacts. For example, Günther and Fink [2010], using pooled survey data from 72 countries, found that the effects of water and sanitation technology on child diarrhea varied across sub-regional country groups, a finding that supports an earlier point made that the most cost-effective intervention could be country-specific [Kremer and Zwame 2007].

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[2] http://www.who.int/mediacentre/factsheet/fs330/en. Accessed 12 April 2016.

In the Philippines, child diarrhea remains a major public health concern. According to the Department of Health, diarrheal diseases are among the top ten causes of infant mortality each year during the period 1995-2010. The results of the last two rounds of the National Demographic and Household Survey reveal a drop from 11 percent in 2010 to 8 percent in 2013 in the proportion of under-5 children who had diarrhea during the two weeks preceding the survey. Based on the country's progress made in 2013, according to the Philippine Statistics Authority (PSA)[3] the country is posed to meet by 2015 its MDG target of bringing down the under-5 mortality rate and infant mortality rate to 27 and 19, respectively. Moreover, the country also appears to have achieved already by 2014 its MDG goals of having around 85 percent of families with access to safe water supply and sanitary toilet facilities. The Philippines also subscribes to the SDGs.

This paper investigates whether the government's continued commitment to sustain household access to safe water and sanitation facilities can help sustain the momentum towards better child health outcomes, particularly on the incidence of diarrhea in under-5 children. Using pooled household samples from nationwide surveys undertaken in 1993, 1998, 2003, 2008, and 2013, this paper extends and updates studies that found some evidence of the beneficial child health effects of proper excreta disposal and improved water quality in the Philippines (Baltazar et al. [1988]; Moe et al. [1991]; van Derslice, Popkin, and Briscoe [1994]; van Derslice and Briscoe [1995]). A caveat on these earlier studies, however, is that while case-control methods were applied, the samples were mainly drawn from the Cebu province and are a bit dated (e.g., prior to 1998). Using more recent 1998 household survey data, Cuesta [2007] found that water and sanitation facilities have positive but not large effects on the nutritional status of children. Arguably, the child's nutritional status improved given access to safe water and sanitation since this access reduced the incidence of diarrhea.[4] Interestingly, Bennett [2012] reports that in Metro Cebu the expansion of piped water may have inadvertently aggravated unsanitary fecal and garbage disposal and thus worsened the incidence of diarrheal diseases.

Following previous studies (e.g., Jalan and Ravallion [2003]; Cuesta [2007]; Kumar and Vollmer [2013]), we apply the propensity score matching technique (PSM) on a subsample of under-5 children culled from the last five rounds of the National Demographic and Health Survey (NDHS), which contain various information including the incidence of child diarrhea, access to different sources of drinking water, and types of toilet facilities. But since these are observational data, PSM allows us to control for possible sources of bias in the estimation of the effects of safe water, sanitation, and hygiene facilities on child health. We

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[3] Philippine Statistics Authority. MDG Watch as of 1 September 2015. http://nap.psa.goc.ph/stats/mdg/mdg_watch_asp. Accessed 13 April 2016.

[4] Guerrant et al. [1992] present some evidence about the effects of diarrhea and malnutrition on each other.

find that improved water and sanitation facilities reduce the incidence of child diarrhea with the results fairly robust to possible unobserved factor bias.

The rest of the paper is organized as follows. Section 2 presents the empirical framework. Section 3 discusses the data used. Section 4 shows the results balancing tests. Section 5 describes the impact estimates in. The last section contains a discussion of the results, the paper's conclusion, and policy implications.

2. Methods

This section describes the PSM technique used to estimate the effect on child health of improved water and sanitation facilities, where households' access to the latter may be due to selection. The same method has been used for the same purpose in, for example, rural India (Jalan and Ravallion [2003]; Fan and Mahal [2011]; Kumar and Vollmer [2013]) and rural Pakistan (Rauniyar, Orberta, and Sugiyarto [2011]). Adapting the convention in the evaluation literature (e.g., Heckman, Ichimura, and Todd [1997]), we indicate health outcome as a binary variable, say, D that takes on a value of 0 (or simply D_{0i}) and 1 (or simply D_{1i}) to denote whether the ith child did or did not have diarrhea, respectively, during the reference period. Further, we denote the ith child's treatment status, which, in this case, is having or not having access to improved sources of drinking water (or improved sanitation facility) with T_i=1 and T_i=0, respectively. As defined by Rosenbaum and Rubin [1983], the propensity score $p(\boldsymbol{X})$ is the conditional probability of receiving treatment given observed characteristics:

$$p(\boldsymbol{X}) \equiv \text{Prob}(T = 1 \mid \boldsymbol{X}) = E\,(T \mid \boldsymbol{X}),$$

where $\boldsymbol{X}$ is a vector of observed characteristics.

Using the propensity score $p(\boldsymbol{X})$, we then match each "treatment" child with a "control" child (or children) to estimate the average treatment effect on the treated (ATT($\boldsymbol{X}$)), as follows:

$$\begin{aligned} \text{ATT}(\boldsymbol{X}) &\equiv \text{E}\{D_{1i} - D_{0i} \mid T_i = 1\} \\ &= [\text{E}\{D_{1i} - D_{0i} \mid T_i = 1, p(X_i)\}] \\ &= \text{E}[\text{E}\{D_{1i} \mid T_i = 1, p(X_i)\} - \text{E}\{D_{0i} \mid T_i = 0, p(X_i)\} \mid T_i = 1]. \end{aligned}$$

For the matching to be valid, two conditions must be satisfied, namely the conditional mean independence , and matching along common support (i.e., for values $0 < p(\boldsymbol{X}) < 1$). Essentially, the first condition ensures that all the characteristics that could have influenced treatment are taken into account in the estimation of the propensity scores and that, after matching, the treatment and paired control units have balanced characteristics (i.e., very similar average characteristics). The common support assumption ensures that each treatment unit, as it were, has a chance of not being treated. If the ATT($\boldsymbol{X}$) < 0, then the intervention (i.e., access to improved water or sanitation facility) is said to have a desired impact on the outcome (i.e., reduced the probability of the child having diarrhea) (Dehejia and Wahba [2002]; Caliendo and Kopeinig [2008]; Wooldridge [2002]).

In our calculation of the ATT($\boldsymbol{X}$), we first obtain the propensity scores from a logistic regression model applied on a sample of children below five years old. Then, we match each treatment child with one control child whose propensity score is within some distance away from that of the former. Specifically, we implement this so-called nearest-1 neighbor (NN1) matching with replacement and set the threshold distance (or caliper size) to 0.001. Following Abadie and Imbens [2006], we derive the standard errors of the estimated ATT($\boldsymbol{X}$) that take into account that the propensity scores are estimates.

To assess the quality of the matching, we perform test of means of each of the covariates, before and after matching. Following Caliendo and Kopeinig [2008], we also compare the pseudo-R^2, the LR χ^2 test statistic and the distribution of the standardized bias[5], before and after matching. The expectations are that after matching the pseudo-R^2 should drop significantly, and there should be significant improvements in the means and standard deviations of the standardized bias. Furthermore, whereas the model does not fail the LR χ^2 test before matching, it should fail the same test after matching. In addition, we use Rubin's B and R statistics with recommended thresholds of B being less than 25 and R being between 0.5 and 2 to consider the samples adequately balanced [Leuven and Sianesi 2003].[6] While there is no guarantee that all the balancing tests will be satisfied after matching, the preponderance of test results indicating balanced matching is sufficient. Finally, we depict the matching along common support using histograms.

Note that the PSM technique is unable to control for selection on unobservable characteristics (e.g. parent's motivation). While there is no way to directly verify the presence or effects of the unobserved factors, it is suggested to perform tests of sensitivity to possible hidden bias due to them [Caliendo and Kopeinig 2008]. Following Kumar and Vollmer [2013], we use the Mantel and Haenszel test procedure to determine the possible effect of such factor on the odds of being included and not included in the treatment group. Without hidden bias, the odds ratio (Γ) is equal to one for the paired treatment and control individuals

[5] Defined for each covariate, the standardized bias is "the difference of sample means in the treated and matched control subsamples as a percentage of the square root of the average sample variances in both groups" [Caliendo and Kopeinig 2008].

[6] According to Leuven and Sianesis [2003], Rubin's B is "the absolute standardized difference of the means of the linear index of the propensity score in the treated and (matched) non-treated group", and Rubin's R is "the ratio of treated to (matched) non-treated variances of the propensity score index".

when matched on the same observed covariates. With hidden bias, the odds ratio could increase, suggesting an overestimation of the treatment effect (Q^{+}_{mh}), or decrease, suggesting an underestimation of the treatment effect (Q^{-}_{mh}). Note that the Mantel and Haenszel tests are not direct proof of the presence of hidden bias, but only how much bias the unobserved factor must induce to undermine the null hypothesis that the observable covariates are enough to account for the bias in the assignment into treatment or control group.

Following Kumar and Vollmer [2013], we also estimate a linear probability model (LPM) to benchmark our impact estimates based on the PSM technique. In particular, we run the following multivariate regression model,

$$D_{ij} = \beta_0 + \beta_1 T_{ij} + \delta X_{ij} + \varepsilon_{ij},$$

where D_{ij} is the outcome for the ith child in the jth household, T is a binary treatment indicator (improved water or improved sanitation), $\boldsymbol{X}$ is vector of child and household level characteristics and dummy variables for regions and years, and ε is the error term. We estimate the above equation with and without weights. The weights used are the inverse of the estimated propensity scores for the treatment child and the inverse of one minus the estimated propensity scores for the control child. As defined, the weights serve to balance the distribution of the covariates and ensure efficiency in the estimates [Hirano, Imbens, and Ridder 2003]. Note that while LPM is used in impact evaluation literature, its validity is based on the assumption that the assignment to treatment is exogenous and random. This is not necessarily the case with observational data where selection bias is likely. Both our LPM and PSM estimates are obtained using STATA [Leuven and Sianesi 2003].

3. Data

The observational data used in this paper are obtained from the 1993, 1998, 2003, 2008, and 2013 rounds of the NDHS[7] for the Philippines. Each NDHS round has a nationally representative sample of households with female members of reproductive age (i.e., 15 to 49 years old).[8] These surveys are conducted to provide demographic, health, and socioeconomic information at the level of both the household and the woman-respondent for the evaluation and design of government policies. In this study, we pooled the sub-samples of households with children younger than five years old in each NDHS round.

Table 1 shows the sample sizes of each of the NDHS rounds. In the 1993 round, there were 15,029 women respondents belonging to 12,995 sample households.

[7] The 1993-2013 NDHS datasets are obtained from ICF Macro (http://www.measuredhs.com).

[8] However, in the 2013 survey round, 3,431 out of 14,804 surveyed households have zero eligible women.

In the succeeding survey rounds, the corresponding samples of women and households are 13,983 and 12,407 in 1998, 13,633 and 12,586 in 2003, 13,594 and 12,469 in 2008, and 16,155 and 14,804 in 2013. Of the sample households, between 44 percent (in 1993) and 36 percent (in 2013) had children younger than five years old. There were samples of 9,195 such children in 1993, 8,083 in 1998, 7,145 in 2003, 6,572 in 2008, and 7,216 in 2013. In our estimation of treatment effects below, we pooled the samples from 1993, 1998, 2003, and 2008 rounds of NDHS, but we kept the sample from the latest NDHS round separately. Arguably, the results from the latest NDHS round are more relevant. Comparing them with the results obtained from previous NDHS rounds, however, will indicate whether the impact of water and sanitation interventions on child health may change with time.

TABLE 1. Sample sizes and distribution of the National Demographic and Health Surveys, Philippines, 1993, 1998, 2003, 2008, and 2013

Samples	1993	1998	2003	2008	2013
Number of women of reproductive age (15-49 years old)	15,029	13,983	13,633	13,594	16,155
Number of households	12, 995	12,407	12,586	12,469	14,804
Number of households with children below 5 years old	5,795	5,240	4,920	4,712	5,301
Number of children below 5 years old	9,195	8,083	7,145	6,572	7,216
Under-5 children by diarrhea condition*	8,770 (100%)	7,669 (100%)	6,825 (100%)	6,327 (100%)	6,833 (100%)
No	7,871 (89.66%)	7,065 (92.12%)	6,076 (89.03%)	5,756 (90.98%)	6,292 (92.09%)
Yes	908 (10.34%)	604 (7.88%)	749 (10.97%)	571 (9.02%)	541 (7.91%)
Under-5 children with access to sources of drinking water (all types)*	9,160	8,075	7,034	6,408	6,833
Under-5 children with access to sanitation facilities (all types)*	9,179	8,052	7,031	6,408	6,83

Notes:
*Sub-samples limited to de jure members of households.
Sources: National Demographic and Health Survey (various rounds); authors' calculations.

3.1. Measuring diarrhea in children

We measure child health using a binary indicator of diarrhea incidence to denote if an under-5 child did or did not have diarrhea in the last two weeks prior to the survey interview. In 1993, about 10 percent of the sample children had diarrhea (Table 1). In 2003, a slightly higher proportion (10.97 percent) had watery stool. The proportions of under-5 children with diarrhea were relatively lower in 1998 and 2013 at 7.88 percent and 7.91 percent, respectively. Note that the diarrhea figures reported in Table 1 and used in the rest of the paper exclude households with missing information (i.e., no answers to the relevant survey questions) and those children who are not *de jure* members of the households (i.e., excluding temporary visitors). Furthermore, at least 97 percent of the sample children in each survey year had access to some type of water or sanitation facility.

3.2. Defining improved water sources and sanitation facilities

Table 2 shows the distribution of samples of under-5 children by their households' main source of drinking water and toilet facilities in each NDHS round. In the top half of Table 2, three observations can be made concerning sources of water for drinking. First, the proportion of under-5 children in households with access to water piped into dwellings, yards, or plots, or with access to public taps steadily declined from 58 percent in 1993 to 49 percent in 2003 and then finally to 32 percent in 2013. Second, consistently across survey years beginning in 1998, at least one in four under-5 children belong to households that collect drinking water from tube wells, bore holes, or protected wells. The last notable observation is the rise in the percentage of children in households that use bottled water, especially in the last two NDHS rounds. By 2013, a higher percentage of children belong to households that use bottled water than piped water.

In the bottom half of Table 2, around 43 percent of sample children in 1993 belong to households that have their own flush toilets. This proportion has steadily increased through the years, reaching about 75 percent in 2008 and 83 percent in 2013. The proportion of children with access to flush toilets shared with other households also rose, from 11 percent in 1993 to 16 percent in 2003, and then sharply fell to less than one percent in 2013. In each NDHS round, at least around 10 percent of the sample children had no access to sanitary toilet facilities. Instead, they used unsafe methods like hanging toilets or defecation in bushes, fields, or rivers, which may have contaminated water sources or food supply and thus led to more diarrhea cases.

Adopting the classification of the WHO and UNICEF [2010], we construct binary indicators to distinguish improved water supply and sanitation facilities from other types. Specifically, *improved water* assumes a value of 1 if the main source of drinking water is piped water, tube well, protected well, protected spring, rainwater, tanker truck or cart with small tank, and 0 otherwise. For the 2013 NDHS, however, we follow the official reclassification of bottled water as an improved source of drinking water [Philippine Statistics Authority and ICF International 2014].[9] The indicator *improved sanitation* assumes the value of 1 if the household owns or exclusively uses a sanitation facility that is a flush toilet (connected to piped sewer system, septic tank, pit latrine), pit latrine (ventilated,

[9] For this reason, it makes sense to analyze the latest NDHS round separately from the first four rounds.

TABLE 2. Distribution of children by main source of drinking water and type of sanitation facility, 1993-2008

Main source/type	1993		1998		2003		2008		2013		WHO classi-fication*
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	
Drinking water (Total)	9,160	100.0	8,075	100.0	7,034	100.0	6,408	100.0	6,833	100.0	
Piped water											
Piped into dwelling	3,463	37.8	1,666	20.6	1,909	27.1	1,206	18.8	1,251	17.8	I
Piped into yard/plot	848	9.3	517	6.4	377	5.4	409	6.4	473	6.7	I
Public tap/stand pipe	971	10.6	1,100	13.6	1,147	16.3	438	6.8	532	7.6	
Tube well water											
Tube well or bore hole							1,500	23.4	1,161	16.6	I
Dug well											
Protected well	387	4.2	2,650	32.8	1,930	27.4	413	6.5	301	4.3	I
Unprotected well/open	2,259	24.7	790	9.8	422	6.0	253	4.0	138	2.0	U
dug							94	1.5	66	0.9	U
Semi-protected well											
Surface water	812	8.9	580	7.2	374	5.3	515	8.0	288	4.1	I
Protected spring			459	5.7	291	4.1	250	3.9	215	3.1	U
Unprotected spring			96	1.0	82	1.2	48	0.8	18	0.3	U
River/lake/ponds/dam	82	0.9	36	0.5	41	0.6	48	0.8	26	0.4	I
Rainwater							56	0.9	34	0.5	I
Tanker truck			150	1.9	127	1.8	40	0.6	1	0.01	I
Cart with small tank			28	0.4	330	4.7	1,066	16.6	2,505	35.7	U
Bottled water							58	0.9			U
Neighbor's tap	338						13	0.2			U
Neighbor's tap (NAWASA)		3.7	3	0.0	4	0.1	1	0.0	5	0.1	U
Others											

TABLE 2. continued

Main source/type	1993		1998		2003		2008		2013		WHO classi-fication*
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	
Sanitation facility (Total)	9,179	100.0	8,052	100.0	7,031	100.0	6,408	100.0	6,833	100.0	
Flush or pour flush toilet											
to piped sewer system							151	2.4	307	4.5	I
to septic tank							3,741	58.4	4,903	71.8	I
to pit latrine							869	13.6	443	6.5	I
to somewhere else							48	0.8	84	1.2	U
flush, don't know where							12	0.2	3	0.04	U
own toilet	3,932	42.8	3,680	45.7	3,837	54.6					I
shared flush toilet	1,016	11.1	1,217	15.1	1,127	16.0			53	0.8	U
Pit latrine											
ventilated, improved							85	1.3	45	0.7	I
with slab							189	3.0	170	2.5	I
without slab/open pit							219	3.4	134	2.0	U
closed pit			731	9.1	484	6.9					I
open pit			825	10.3	362	5.2					U
own toilet (sanitary pit)	1,027	11.2									I
shared toilet (sanitary pit)	407	4.4									U
Open privy	797	8.7									U
Composting toilet							53	0.8	8	0.1	I
Bucket toilet							10	0.2	5	0.1	U
Drop/hanging toilet	354	3.9	301	3.7	257	3.7	102	1.6	50	0.7	U
No facility/bush/field/river	1,635	17.8	1,292	16.1	962	13.7	925	14.4	618	9.0	U
Other	11	0.1	6	0.1	2	0.0	4	0.1	12	0.2	U

Notes:
*"I" means improved and "U" means unimproved. In the 2013 NDHS, "bottled water" is classified under improved source of drinking water and "shared flush toilet" is classified under "public toilet," which can be improved or non-improved.
Samples limited to *de jure* members of the household.
Source of raw data: National Demographic and Health Surveys (various years); authors' calculations

improved, with slab, closed pit), or composting toilet, and 0 otherwise. "Shared, flush toilet" is reclassified as "public toilet" in the 2013 NDHS. Consistently across survey years, majority of the households have access to improved water sources or improved sanitation facilities.

3.3. Covariates

Following similar studies (e.g., Jalan and Ravallion [2003]; Cuesta [2007]; Rauniyar, Orbeta, and Sugiyarto [2011]; Kumar and Vollmer [2013]), the list of covariates used here includes indicators of parental preferences, individual and household-level socioeconomic characteristics, and community-level factors that affect the children's access to safe water supply and sanitary toilets, and which in turn determine their susceptibility to diarrheal diseases. This is based on the assumption that parents, particularly mothers, generally decide on the allocation of family resources and on matters that affect their children's health.

Tables 3 and 4 show the pre-matching means of the specific covariates used in the analysis of the impacts of improved water and improved sanitation, respectively. In each of the tables, the top half pertains to treatment and control households from the pooled samples of the first four NDHS rounds (1993-2008); the bottom half pertains to household samples in the 2013 NDHS round.

In the top half of Table 3, the two groups of households are found significantly different in their average characteristics, except in terms of proportion of mothers' whose age ranges from 21 to 30 years (*mother's age is 21-30 years*), proportion of household heads' whose age ranges from 31 to 40 years (*head's age is 31-40 years*), and proportion of households with 2-5 members (*household size is 2-5 members*). They differ in terms of proportions of mothers who are younger than 21 years (*mother's age is below 21 years*) or who finished at secondary education (*mother finished high school*), parents married or living together (*in union*), or head is a Cebuano (*Cebuano*). Further, the proportions are also significantly different in terms of living in the National Capital Region (*National Capital Region*) or anywhere else in the island of Luzon (*Rest of Luzon*) or in the southern island of Mindanao (*Mindanao*), which are used here as possible proxy variables for supply-side or community-level variables that could affect access to water facilities or susceptibility to diarrheal diseases.

Among the country's 17 regions, the National Capital Region is the richest in terms of gross domestic product per capita. By the same metric, the island group of Mindanao is relatively poorer than the other two major island groups in the country. Significant differences are also noted in terms of socioeconomic indicators, particularly whether the house has electricity (*electricity*), with at most 1 room exclusively for sleeping (*Number of rooms for sleeping is 0-1*), and whether the household belongs to the first or second wealth quintile (*lowest two wealth quintiles*). Adopting the method in Gwatkin et al. [2007], the wealth quintiles are constructed for each survey round using principal component analysis and based on household amenities, type of housing materials used, and tenure status.[10] To account for possible time specific unobserved factors, a dummy variable for the year 2008 is included.

TABLE 3. Improved water: means of household-level covariates before matching

Covariates	Means		Percentage bias	*t*-test (1) – (2)
	Treatment (1)	Control (2)		
1993-2008				
Mother's age is below 21 years	0.0496	0.0615	-5.2	3.76***
Mother's age is 21–30 years	0.5088	0.4999	1.8	1.24
Mother finished high school	0.4207	0.2977	25.8	17.84***
Head's age is 31–40 years	0.3868	0.3888	-0.4	-0.28
Household size is 2–5 members	0.4164	0.4200	-0.7	-0.51
In union	0.9654	0.9727	-4.2	-2.90***
Cebuano	0.2721	0.3052	-7.3	-5.21***
Rest of Luzon	0.410	0.3123	20.5	14.25***
National Capital Region	0.0949	0.0870	2.7	1.90*
Mindanao	0.3165	0.3349	-3.9	-2.78***
Electricity	0.6780	0.4383	49.7	35.7***
Number of rooms for sleeping is 0-1	0.3260	0.4208	-19.7	-14.09***
Lowest two wealth quintiles	0.2653	0.4811	-45.8	-33.44***
Year 2008	0.2002	0.2511	-12.2	-8.81***
Number of observations	22,520	6,379		
2013				
Child is less than one year old	0.195	0.206	-2.8	-0.60
Mother's age is 21-40 years	0.852	0.806	12.2	2.77***
Mother is employed	0.391	0.340	10.5	2.25**
Mother finished high school	0.600	0.287	66.6	13.93***
In union	0.954	0.992	-23.9	-.4.09***
Father's age is 21-30 years	0.357	0.407	-10.2	-2.23**
Father is employed	0.985	0.994	-9.2	1.69*
Father finished high school	0.545	0.221	70.5	14.20***
Head is male	0.880	0.970	-34.9	-6.19***
CCT beneficiary family	0.302	0.431	-27.0	-6.04***
PhilHealth coverage	0.592	0.551	8.1	1.76*
Rest of Luzon	0.360	0.243	25.6	5.30***
Visayas	0.167	0.136	8.6	1.80*
Mindanao	0.253	0.555	-64.2	-14.73***
Household size is below 6	0.468	0.395	14.7	3.15***
Electricity	0.838	0.441	90.9	22.63***
No separate room for sleeping	0.003	0.014	-11.4	-3.57***
Lowest two wealth quintiles	0.472	0.872	-94.0	-17.67***
Third wealth quintile	0.200	0.091	31.3	6.01***
Number of observations	6,072	506		

*$p < 0.10$
**$p < 0.05$
***$p < 0.01$

[10] Our own computed factor scores correlate highly (0.96) with the factor scores reported in either the 2003 and 2008 NDHS rounds.

In the bottom half of Table 3, we see that the treatment and control households differ greatly in terms of average characteristics before matching, except in the variable that indicates whether the child is less than a year old (*child is less than one year old*). They differ in other binary indicators measuring the parents' characteristics (*mother's age is 21-40 years*, *mother is employed*, *father's age is 21-30 years*, *father finished high school*), income status or poverty status (*CCT beneficiary family*, *lowest two quintiles*, *third wealth quintile*), other socioeconomic characteristics (*no separate room for sleeping*, *household size is below 6*, *PhilHealth coverage*, *electricity*), and location (*Rest of Luzon*, *Visayas*, *Mindanao*). The dummy variable NDHS *beneficiary family* indicates whether the child belongs to a household that reports to be a beneficiary the government's conditional cash transfer program (also known as the "Pantawid Pamilyang Pilipino Program"), which is extended to poor families with school-age children or pregnant women members. The dummy variable *PhilHealth coverage* indicates whether the child belongs to household that is covered under the country's social health insurance program (also known as "PhilHealth").

In the top half of Table 4, we also note that the two household groups differ systematically in all covariates. A greater proportion of the treatment households (60 percent) than of the control households (31 percent) reported to have spent 0 minute when they tap their main source for drinking water, which in this case would indicate that the source is piped water or is inside their house or yard. They also differ in mother's characteristics (*Mother's age is below 30 years*, *mother is employed*), father completed at least some years of college education (*father has some college education*), and the head's age (*head's age is 31-40 years*). Also, a bigger proportion of the treatment households than the control households have more household members (*household size is greater than 5*), whose heads are Ilocano (*Ilocano*), live in Luzon but outside Metro Manila (*Rest of Luzon*) or in Mindanao but outside the Autonomous Region of Muslim Mindanao (*Rest of Mindanao*). The treatment household also appears to be better off: more of them have access to electricity (76 percent vs. 40 percent), and fewer of them belong to the lowest two wealth quintiles (18 percent vs. 52 percent), or live in the Autonomous Region of Muslim Mindanao (2.7 percent vs. 11.6 percent).[11] Again, to account for unobserved temporal sources of variations in access to sanitation facilities, binary indicators for the year 1993 (*Year 1993*) and for the years 2003 and 2008 (*Year 2003-2008*) are included as covariates.

[11] Relative to other regions in the country, the Administrative Region of Muslim Mindanao consistently performs poorly in terms of human development indicators [Human Development Network 2005].

TABLE 4. Improved sanitation: means of household-level covariates before matching

Covariates	Means		Percentage bias	*t*-test (1) – (2)
	Treatment (1)	Control (2)		
1993-2008				
Time to water source is 0 minute	0.6115	0.3134	62.7	51.6***
Mother's age is below 30 years	0.5380	0.5924	-11.0	-9.08***
Mother is employed	0.4501	0.3235	26.2	21.55***
Father has at least some college education	0.3093	0.0956	55.2	43.63***
Head's age is 31–40 years	0.3821	0.3955	-2.8	-2.28**
Household size is greater than 5	0.5994	0.5564	8.7	7.23***
Ilocano	0.1133	0.0723	14.1	11.4***
Cebuano	0.2636	0.3044	-9.0	-7.52***
Rest of Luzon	0.2677	0.2449	5.2	4.32***
Rest of Mindanao	0.4323	0.3200	23.4	19.23***
Autonomous Region of Muslim Mindanao	0.0272	0.1163	-35.1	31.19***
Electricity	0.7671	0.4000	80.3	67.58***
Lowest two wealth quintiles	0.1805	0.5230	-76.8	-65.52***
Year 1993	0.2636	0.3531	-19.5	-16.28***
Year 2003-2008	0.5052	0.3442	33.0	27.17***
Number of observations	17,725	11,174		
2013				
Water on premises	0.358	0.420	-12.9	-4.34***
Child is less than one year old	0.196	0.201	-1.2	-0.39
Child is male	0.511	0.528	-3.3	-1.12
Mother's age is 21-40 years	0.854	0.851	0.9	0.30
Mother is employed	0.429	0.332	20.1	6.65***
Mother finished high school	0.679	0.519	33.1	11.23***
In union	0.950	0.964	-7.0	-2.27**
Ilocano	0.087	0.122	-11.3	-3.91***
Father's age is 21-30 years	0.346	0.406	-12.4	-4.19***
Father is employed	0.983	0.984	-0.6	-0.19
Father finished high school	0.630	0.451	36.5	12.29***
Head is male	0.860	0.916	-17.9	-5.73***
CCT beneficiary family	0.261	0.313	-11.4	-3.87***
PhilHealth coverage	0.628	0.540	17.9	6.04***
Rest of Luzon	0.388	0.346	8.6	2.87***
Visayas	0.171	0.116	15.6	5.07***
Mindanao	0.229	0.283	-12.5	-4.23***
Urban	0.432	0.447	-3.0	-1.00
Household size is below 6	0.438	0.538	-20.1	-6.73***
Electricity	0.881	0.838	12.3	4.24***
Rooms for sleeping 0-1	0.322	0.557	-48.7	-16.50***
Lowest two wealth quintiles	0.353	0.610	-53.3	-17.92***
Third wealth quintile	0.207	0.214	-1.5	-0.51
Number of observations	3,866	1,577		

*$p < 0.10$
**$p < 0.05$
***$p < 0.01$

In the lower half of Table 4, the treatment and control households in 2013 still have different pre-treatment characteristics. They systematically differ in 17 of the 23 covariates, which now include binary indicators of whether water is immediately accessible (*water on premises*), child characteristics (*child is less than one year old*, *child is male*), and other additional parental, household-level and location characteristics as those in found in Table 3. All in, the results in Tables 3 and 4 show wide, systematic differences between the two household groups in characteristics that may account for their varying access to improved water sources or improved toilet facilities or in the incidence of diarrhea in their young members.

4. Balance diagnostics

The reliability of the impact estimates depends largely on the quality of the counterfactual, which in this case is determined by the quality of the matching. Table 5 and Table 6 show the results of the logistic regression and the tests of means for improved water and improved sanitation, respectively. Most of the 14 covariates in the top half of Table 5 (for the pooled 1993-2008 samples) are statistically significant. The four statistically insignificant variables include three covariates—mother's age is 21-30 years, head's age is 31-40 years, and household size is 2-5 members—that are already balanced before matching. The fifth column of the table shows large percentage reductions in absolute bias for most covariates after matching. In the last column, the results of the tests of means indicate an overall balance in the distribution of all covariates after matching, except for the variable in union.

In the bottom half of Table 5, we note that most of the coefficients of the 19 covariates are statistically significant. The six covariates that are not statistically significant are child is less than one year old, mother's age is 21-40 years, mother is employed, father is employed, PhilHealth coverage, and no separate room for sleeping. The last column indicates that treatment households and the matched control households achieved balanced averages in only six of the 19 characteristics. However, the large percentage reductions in absolute bias suggest that differences in the means are much smaller after matching than before.

TABLE 5. Improved water: logistic regression estimates and covariate balance after propensity score matching (individual *t*-test)

Variables	Propensity score, logit		Means after nearest-neighbor matching, caliper (0.001)			
	Coefficient	Standard error	Treatment (1)	Control (2)	Percentage reduction |bias|	*t*-test (1)-(2)
1998-2008						
Mother's age is below 21 years	-0.120*	0.067	0.049	0.050	92.5	-0.44
Mother's age is 21–30 years	0.003	0.033	0.509	0.510	91.9	-0.15
Mother finished high school	0.059*	0.035	0.421	0.427	95.1	-1.30
Head's age is 31–40 years	0.018	0.031	0.387	0.381	-188.2	1.23
Household size is 2–5 members	0.002	0.032	0.416	0.421	-40.9	-1.07
In union	-0.225**	0.088	0.967	0.971	41.3	-2.63***
Cebuano	0.024	0.036	0.272	0.269	92.5	0.60
Rest of Luzon	0.561***	0.042	0.411	0.411	100.0	-0.01
National Capital Region	-0.034	0.061	0.095	0.097	75.0	-0.71
Mindanao	0.403***	0.039	0.317	0.313	80.6	0.81
Electricity	0.852***	0.051	0.679	0.681	99.0	-0.56
Number of rooms for sleeping is 0-1	-0.155***	0.032	0.325	0.323	97.9	0.45
Lowest two wealth quintiles	-0.232***	0.050	0.264	0.264	99.8	0.13
Year 2008	-0.474***	0.036	0.198	0.199	99.3	-0.09
Constant	0.891***	0.104				
Number of observations		28899	22438	6379		
2013						
Child is less than one year old	-0.059	0.125	0.192	0.176	-50.3	2.10**
Mother's age is 21-40 years	0.178	0.129	0.854	0.837	63.0	2.31**
Mother is employed	-0.150	0.109	0.381	0.445	-26.7	-6.42***
Mother finished high school	0.269**	0.124	0.553	0.524	90.9	2.82***
In union	-1.04*	0.532	0.976	0.972	89.2	1.29
Father's age is 21-30 years	-0.289***	0.108	0.377	0.385	84.5	-0.78
Father is employed	-0.609	0.609	0.989	0.981	7.3	3.50***
Father finished high school	0.348***	0.133	0.489	0.480	98.3	0.53
Head is male	-0.783***	0.125	0.921	0.937	82.6	-3.01***
CCT beneficiary family	0.230*	0.124	0.334	0.346	90.0	-1.33
PhilHealth coverage	-0.064	0.119	0.585	0.569	58.7	1.65*
Rest of Luzon	-0.606***	0.202	0.364	0.326	67.7	3.90***
Visayas	-0.473**	0.221	0.166	0.149	47.8	2.18**
Mindanao	-1.253***	0.192	0.288	0.311	92.2	-2.51**
Household size is below 6	0.316***	0.108	0.467	0.441	64.6	2.54**
Electricity	1.018***	0.28	0.824	0.809	96.2	1.80*
No separate room for sleeping	-0.192	0.473	0.002	0.002	98.0	0.21
Lowest two wealth quintiles	-1.810***	0.258	0.542	0.521	94.6	2.12**
Third wealth quintile	-1.186***	0.280	0.228	0.222	94.9	0.66
Constant	5.996***	0.863				
Number of observations		5,330	4,824	506		

*$p < 0.10$
**$p < 0.05$
***$p < 0.01$

TABLE 6. Improved sanitation: logistic regression estimates and covariate balance after propensity score matching (individual *t*-test)

Variables	Propensity score, logit		Means after nearest-neighbor matching, caliper (0.001)			
	Coefficient	Standard error	Treated (1)	Control (2)	Percentage reduction |bias|	*t*-test (1)-(2)
1993-2008						
Time to water source is 0 minute	0.697***	0.030	0.607	0.610	99.1	-0.54
Mother's age is below 30 years	-0.213***	0.030	0.542	0.547	89.3	-1.09
Mother is employed	0.152***	0.029	0.448	0.446	98.7	0.30
Father has at least some college education	0.884***	0.040	0.301	0.292	95.7	1.88*
Head's age is 31–40 years	-0.080***	0.029	0.383	0.374	31.5	1.77*
Household size is greater than 5	0.278***	0.030	0.598	0.594	91.8	0.68
Ilocano	0.227***	0.051	0.111	0.113	96.5	-0.42
Cebuano	-0.113***	0.036	0.264	0.262	96.6	0.29
Rest of Luzon	0.401***	0.037	0.433	0.443	90.9	-1.93*
Rest of Mindanao	0.707***	0.039	0.263	0.263	99.8	0.01
Autonomous Region of Muslim Mindanao	-1.184***	0.065	0.028	0.025	97.6	1.27
Electricity	0.623***	0.047	0.764	0.767	99.3	-0.59
Lowest two wealth quintiles	-0.681***	0.048	0.183	0.181	99.6	0.36
Year 1993	-0.048	0.036	0.265	0.258	92.3	1.47
Year 2003-2008	0.503***	0.035	0.501	0.496	97.2	0.85
Constant	-0.682***	0,065				
Number of observations		**28899**	**17518**	**11174**		
2013						
Water on premises	-0.164**	0.066	0.363	0.390	56.1	-2.43***
Child is less than one year old	-0.001	0.081	0.196	0.182	-190.4	1.49
Child is male	-0.127**	0.064	0.513	0.531	-7.5	-1.54
Mother's age is 21-40 years	0.006	0.092	0.854	0.845	-195.8	1.11
Mother is employed	0.120*	0.069	0.421	0.447	73.3	-2.24**
Mother finished high school	0.267***	0.077	0.670	0.666	97.4	0.37
In union	-0.072	0.175	0.954	0.965	21.1	-2.43**
Ilocano	-0.602***	0.111	0.089	0.106	52.0	-2.40**
Father's age is 21-30 years	-0.147**	0.069	0.351	0.354	95.0	-0.27
Father is employed	0.256	0.255	0.983	0.981	-171.6	0.62
Father finished high school	0.331***	0.077	0.617	0.607	93.9	0.96
Head is male	-0.260**	0.113	0.867	0.875	85.5	-1.04
CCT beneficiary family	0.078	0.083	0.267	0.293	48.3	-2.55**
PhilHealth coverage	0.153**	0.071	0.161	0.138	59.2	2.68***
Rest of Luzon	0.394***	0.089	0.385	0.428	-2.3	-3.71***
Visayas	0.682***	0.116	0.161	0.138	59.2	2.68***
Mindanao	0.165*	0.094	0.234	0.232	95.0	0.28
Urban	-0.313***	0.073	0.443	0.383	-307.8	5.27***
Household size is below 6	-0.256***	0.070	0.444	0.464	80.1	-1.71*
Electricity	-0.337***	0.098	0.876	0.874	94.9	0.28
Rooms for sleeping 0-1	-0.519***	0.071	0.336	0.345	95.9	-0.86
Lowest two wealth quintiles	-1.205***	0.098	0.367	0.364	98.8	0.27
Third wealth quintile	-0.771***	0.097	0.216	0.209	-17.7	0.77
Constant	1.939***	0.338				
Number of observations		5,443	3,673	1,577		

*$p < 0.10$
**$p < 0.05$
***$p < 0.01$

In the top half of Table 6, all covariates, except for the year 1993, have statistically significant regression coefficients. The results of the test of means show that the treatment households and matched control households have generally balanced characteristics. In the bottom half of the table, we see that 18 of the 23 covariates have statistically significant coefficients. Those that have insignificant results are child is less than one year old, mother's age is 21-40 years, in union, father is employed, and CCT beneficiary family. Most of the 23 covariates have means that are roughly the same for the treatment and matched control households after matching. Even for those covariates with unbalanced means after matching, the treatment and matched control households have become more alike, as evidenced by the large percentage reductions of the standardized bias.

The quality of the matching is further assessed in Table 7. For improved water, in the pooled samples of households from the 1993-2008 NDHS rounds, the pseudo-R^2 dropped from 0.057 before matching to 0.000 after matching, which indicates that after matching, the model, as it were, does not anymore explain the variations in propensity scores. Before matching, the null hypothesis that the covariates are jointly significant cannot be rejected; however, it can be now rejected after matching since $p > 0.10$ for the LR χ^2 test. Also, the mean of the standardized bias fell from 14.29 to 0.69 after matching.

For the 2013 sample of households, the pseudo-R^2 also improved from 0.187 before matching to 0.01 after matching. Despite the big drop in absolute value, the LR χ^2 statistic remains statistically significant after matching. Nonetheless, the mean of the standardized bias fell from 32.6 to below the desired threshold (below five) after matching. Moreover, the Rubin's *B* and *R* statistics are well within the recommend cut-offs after matching.

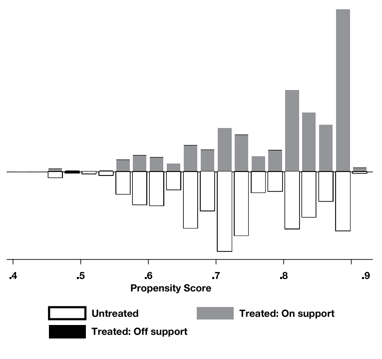
Roughly similar results are obtained in the case of improved sanitation, as reported in the bottom half of Table 7. For the pooled household sample from the first four NDHS rounds, the pseudo-R^2 decreased from 0.187 to 0.0 after matching. Furthermore, the null hypothesis that the covariates are jointly equal to zero can be rejected at $p > 0.5$. The mean of the standardized bias dropped from 30.86 to 0.95. For the 2013 samples, the pseudo-R^2 improved likewise after matching, dropping from 0.11 to less than 0.01. Despite this, the hypothesis that all the covariates are jointly significant cannot be rejected. However, matching also resulted in a big improvement in the mean of the standardized bias, from 15.7 to 3.6. In this case, matching has also reduced the Rubin's *B* and *R* statistics within the desired range.

TABLE 7. Pseudo-R^2 and LR χ^2 mean and median, standard deviation of absolute bias, Rubin's *B* and *R* statistics

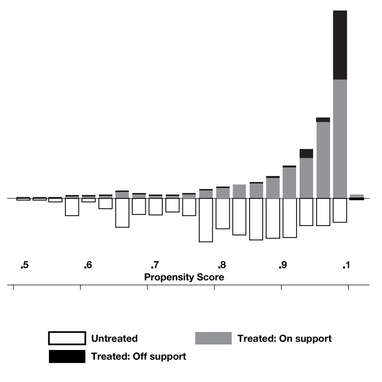
	Pseudo-R^2	LR χ^2	$p > \chi^2$	Mean |Bias|	Median |Bias|	B	R
A. Improved water							
1993-2008							
Unmatched	0.057	1740.54	0.000	14.3	6.2	61.5*	1.10
Matched	0.000	13.63	0.478	0.70	0.5	3.5	1.08
2013							
Unmatched	0.187	667.89	0.000	32.5	23.9	134.5*	1.86
Matched	0.010	131.06	0.000	4.6	4.5	23.4	0.86
B. Improved sanitation							
1993-2008							
Unmatched	0.187	7212.63	0.000	30.9	23.4	111.1*	0.91
Matched	0.000	23.19	0.080	0.9	0.7	5.1	1.04
2013							
Unmatched	0.109	713.53	0.000	15.7	12.4	84.1*	1.23
Matched	0.008	80.85	0.000	3.6	2.6	21.0	1.02

*If *B* > 25%, *R* outside [0.5; 2].

The distributions of the matched samples where their propensity scores overlap are depicted in Figure 1 for improved water and in Figure 2 for improved sanitation. In panel a (1993-2008) and panel b (2013) of Figure 1, we see that that greater mass of the treatment and matched control households have propensity scores greater than 0.6. In panel b, however, we find that a significant mass of households has propensity scores greater than 0.9. In Figure 2, we find that most of the treatment households in both panel a (1993-2008) and panel b (2013) have propensity scores between 0.6 and 0.9. In contrast, most of the matched control households in both panels have propensity scores between 0.3 and 0.8. Note that in both figures a number of treatment households, especially those with high propensity scores, are dropped because they lack suitable matches.

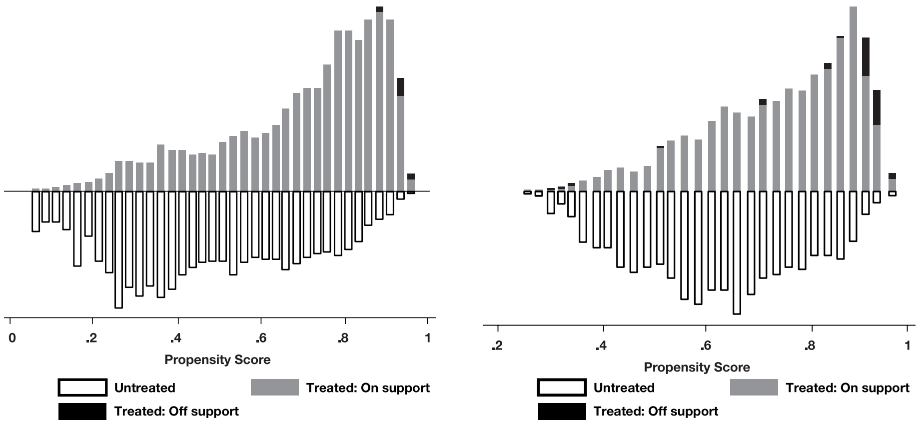


a. 1993-2008



b. 2013

FIGURE 1. Improved water: histograms of matched sub-samples along common support based on NN1(0.001) matching



a 1993-2008 b. 2013

FIGURE 2. Improved sanitation: histograms of matched sub-samples along common support based on NN1(0.001) matching

5. Impact estimates

The ATT(*X*) estimates for improved water and improved sanitation are shown in Table 8 and Table 9, respectively. In Table 8, the impact estimate using PSM is a reduction of around 2 percentage points in the incidence rate of child diarrhea for the sample comprising households surveyed in the first four NDHS rounds. A bigger impact estimate—a reduction of around 8 percentage points—is derived when PSM is applied on the sample culled from the 2013 NDHS. Both impact estimates are highly statistically significant ($p < 0.01$). Roughly the same percentage point reductions in the incidence rate of child diarrhea and levels of statistical significance are obtained using LPM with propensity scores as weights. The unweighted LPM estimates are much smaller in absolute values and are not statistically significant.

In Table 9, the PSM results indicate that improved sanitation lead to around two percentage points reduction in the incidence rate of child diarrhea. However, only the estimate for the pooled sample from the 1993-2008 sample is statistically significant (at $p < 0.01$). The weighted LPM estimate is about one percentage point reduction in the incidence rate, which is also statistically significant (at $p < 0.05$). The weighted LPM estimate for 2013 is positive, but it is not statistically significant from zero. The unweighted LPM estimates are negative, but are likewise not statistically significant from zero.

TABLE 8. Average treatment effect of improved water

	PSM (NN 1) (1)	LPM[b] without weights (2)	LPM[b] with weights (3)
Improved water (1993-2008)	-0.0187***	-0.004	-0.009***
	(0.005)[a]	(0.004)[c]	(0.003)[c]
N	28,817	28,899	53,466
R-squared		0.004	0.004
Improved water (2013)	-0.071***	0.009	-0.073***
	(0.029)[a]	(0.013)[c]	(0.006)[c]
N	6,587	6,578	12,169
R-squared		0.006	0.100

Notes:
[a] The standard errors are computed using the procedure proposed by Abadie and Imbens [2006] that take into account that the propensity scores are estimates.
[b] For the improved water regression, the covariates are mother's age and educational attainment, head's age, household size, in union, Cebuano, number of rooms for sleeping, electricity, child is male, dummy variables for regions and years, and wealth quintiles. For the improved sanitation regression, the covariates are time to water is 0 minutes, mother's age and employment status, father's college education, head's age, household size, Ilocano, Cebuano, electricity, child is male, dummy variables for regions and years, and wealth quintiles.
[c] Figures in parentheses are robust standard errors.
***$p < 0.001$

TABLE 9. Average treatment effect of improved sanitation

	PSM (NN 1) (1)	LPM[b] without weights (2)	LPM[b] with weights (3)
Improved water (1993-2008)	-0.0195***	-0.005	-0.006**
	(0.007)[a]	(0.004)[c]	(0.003)[c]
N	28,692	28,899	55,259
R-squared		0.005	0.005
Improved water (2013)	-0.0193	-0.002	0.006
	(0.008)[a]	(0.009)[c]	(0.005)[c]
N	5,250	5,443	10,492
R-squared		0.001	0.014

Notes:
[a] The standard errors are computed using the procedure proposed by Abadie and Imbens [2006] that take into account that the propensity scores are estimates.
[b] For the improved sanitation regression, the covariates are mother's age and educational attainment, head's age, household size, in union, Cebuano, number of rooms for sleeping, electricity, child is male, dummy variables for regions and years, and wealth quintiles. For the improved sanitation regression, the covariates are time to water is 0 minutes, mother's age and employment status, father's college education, head's age, household size, Ilocano, Cebuano, electricity, child is male, dummy variables for regions and years, and wealth quintiles.
[c] Figures in parentheses are robust standard errors.
***$p < 0.001$

While the previous tests established the balance in their observable characteristics, the matched treatment children and control children may still differ systematically due to unobserved characteristics. Table 10 shows the results of the Mantel and Haenszel tests for improved water. For the 1993-2008 sample, the impact estimates do not seem to be particularly sensitive to hidden bias. For 2013 sample, however, there are indications that unobserved factors, if they exist, may lead us to either overestimate or underestimate the true impacts. The misestimates are likely, however, when the unobserved factors increase the odds of differential assignment into the treatment or matched control groups by only 20 percent or less.

TABLE 10. Improved water: sensitivity analysis using Mantel and Haenszel [1959] bounds for variable diarrhea

Γ	1993-2008				2013			
	Q^+_{mh}	Q^-_{mh}	p^+_{mh}	p^-_{mh}	Q^+_{mh}	Q^-_{mh}	p^+_{mh}	p^-_{mh}
1.0	2.13	2.13	0.02	0.02	-0.060	-0.060	0.524	0.524
1.2	6.00	1.67	0.00	0.05	0.907	0.976	0.182	0.165
1.4	9.30	4.94	0.00	0.00	1.778	1.857	0.038	0.032
1.6	12.19	7.79	0.00	0.00	2.540	2.627	0.006	0.004
1.8	14.79	10.32	0.00	0.00	3.222	3.315	0.001	0.000
2.0	17.15	12.61	0.00	0.00	3.841	3.939	0.000	0.000
2.2	19.32	14.70	0.00	0.00	4.409	4.511	0.000	0.000
2.4	21.34	16.62	0.00	0.00	4.937	5.041	0.000	0.000

Notes:
Gamma (Γ): odds of differential assignment by 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)

The results of the Mantel and Haenszel tests for improved sanitation are shown in Table 11. Overall, the results are similar to those in the previous table. The impact estimates for the 1993-2008 pooled sample are also fairly robust to possible unobserved heterogeneity. The estimate of the treatment effect for the 2013 sample is possibly sensitive to hidden bias. In this case, however the Mantel and Haenszel test results indicate that the unobserved factors, if they exist, may lead to an underestimate of the true impact.

TABLE 11. Improved sanitation: sensitivity analysis using Mantel and Haenszel [1959] bounds for variable diarrhea

Γ	1993-2008				2013			
	Q^+_{mh}	Q^-_{mh}	p^+_{mh}	p^-_{mh}	Q^+_{mh}	Q^-_{mh}	p^+_{mh}	p^-_{mh}
1.0	3.73	3.73	0.00	0.00	1.458	1.458	0.072	0.072
1.2	8.08	0.56	0.00	0.29	2.952	-0.023	0.002	0.510
1.4	11.81	4.22	0.00	0.00	4.231	1.159	0.000	0.123
1.6	15.07	7.41	0.00	0.00	5.357	2.253	0.000	0.012
1.8	18.00	10.24	0.00	0.00	6.368	3.223	0.000	0.000
2.0	20.67	12.80	0.00	0.00	7.290	4.099	0.000	0.000
2.2	23.12	15.13	0.00	0.00	8.139	4.898	0.000	0.000
2.4	25.39	17.28	0.00	0.00	8.930	5.635	0.000	0.000

Notes:
Gamma (Γ): odds of differential assignment by 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)

6. Discussion and conclusion

Results from the application of the PSM technique on several rounds of nationally-representative NDHS show that improved water sources and sanitation facilities reduce diarrhea in under-5 children. The analysis of the 2013 sample shows that access to improved water reduces the incidence rate of child diarrhea by as much as 7 percentage points. This is greater by about 5 percentage points compared to the impact of improved water on the incidence of child diarrhea in the combined 1993-2008 sample.

The analysis of the 2013 sample shows that improved sanitation nominally reduces the incidence of child diarrhea by two percentage points. Statistical tests, however, show that this 2013 estimate is not statistically significant. For the pooled 1993-2008 sample, however, the results show that improved sanitation leads to a statistically significant reduction of child diarrhea by two percentage points. Moreover, the results underscore the merits of controlling for possible selection on observables when using observational data, and the advantages of PSM over LPM in estimating impacts with observational data.

One possible explanation for the higher impact of improved water in the 2013 NDHS sample is the reclassification of bottled water as an improved water source. To ascertain this, further exercises can be done. One exercise is to compare the effect on child health of bottled water alone with that of unimproved water as defined here. The comparison should reveal whether bottled water by itself has the desired impact on child health.

A possible explanation for the nil effect of improved sanitation in latest survey round is that a huge majority (around 90 percent) of the under-5 children belong to households with their own flush toilets or pit latrines (ventilated or with slab). With this lack of variation of households in their treatment assignments, it is difficult to compute the counterfactual (i.e., diarrhea incidence without access to improved sanitation). Where treatment assignment is more varied, as in the case of earlier NDHS rounds, improved sanitation is shown to reduce the likelihood of child diarrhea.

Our estimates are broadly consistent with but lower in magnitudes than results of previous studies in the Philippines. Similar to our findings for 1993, van Derslice and Briscoe [1995] and Baltazar et al. [1988], for example, found through the use case control methods that improvements in water quality and excreta disposal reduced diarrhea episodes among infants and children below two years old. Also applying PSM technique on the 1998 NDHS data, Cuesta [2007] reported that the provision of water and sanitation have positive, although not substantial, impacts on child nutritional status. Interestingly, he found as well that community-based piped water and flush toilets had the greatest potential impact on nutritional status. In a later study Capuno, Tan, and Fabella [2011] also found piped water and flush toilets to have their desired effect on child diarrhea in rural Philippines.

Notwithstanding the data limitations, the results provide support to public interventions that promote access to improved water sources and improved sanitations as measures to protect young children from diarrhea. However, care should be taken in targeting the intervention since the impact estimates is true only for households with the similar observed characteristics as those in our evaluation sample. Besides wider access, it is important as well to maintain or improve the quality of drinking water. The quality of piped water at the point of use should be monitored and promoted, either through advocacy of better hygiene practices and use of safe water containers, and also to educate the public about the true quality of expensive bottled water. ■

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