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Household decisions and child health: Estimating the links between water treatment and the incidence of diarrhea using non-recursive two-equation causal models*

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Abstract

The treatment of drinking water is advocated to reduce the incidence of child diarrhea. However, evaluating the impact of water treatment with only observational data leads to biased estimates since it could be the occurrence of child diarrhea that induced the household to treat their drinking water. To deal with the possible simultaneity between the treatment of drinking water and the incidence of child diarrhea, we specify non-recursive two-equation causal models and apply it on a sub-sample of households with children below five years old from the Philippine National Demographic and Health Surveys. In the treatment effects model, we find that the treatment of drinking water reduces by 5.2 percentage points the proportion of under-5 children afflicted with diarrhea. In the instrumental-variable probit model, we find that households have a higher propensity to sterilize their drinking water by 1.2 percentage points given a one percentage point increase in the proportion of under-5 children with diarrhea. Ignoring the simultaneity yields the misleading result that water treatment increases the incidence child diarrhea. These results underscore the need to insure the quality of drinking water at the point of use and not just at the point of source.

Running head: Causal links between water treatment and child diarrhea

Key words: causal effects, household water treatment, child diarrhea

JEL Codes: I12, I18, H51

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I. Introduction

Households adopt both preventive and curative measures to improve their children's health. Some measures may be undertaken either before or after the onset of a disease or illness. To evaluate the impact of such measures, information on the timing of their adoption matters.. One such measure is the household treatment of drinking water, which is advocated as part of water, sanitation and hygiene-related interventions to reduce the incidence of child diarrhea (UNICEF/WHO, 2009; Fewtrell et al, 2005). Conceivably, however, some households boil, filter or add chlorine to their drinking water only after the onset of diarrhea to contain its spread to other household members. Thus, the decision to adopt this sanitary practice and the observed incidence of diarrhea may well have causal effects on each other. With only observational data and without information on when the practice of treating drinking water is adopted, estimates of the causal effect of water treatment on the incidence of child diarrhea may be biased and misleading.

In this paper, we show evidence of the simultaneity bias and provide estimates of the marginal and independent causal effects between water treatment and the incidence of child diarrhea by estimating a two-equation causal (simultaneous equations) models. We adopt a household-level analysis to account for the possibility that the decision to treat drinking water to benefit all children in the household and not just those children who have diarrhea. Also, the household-level analysis accounts for the panel structure of diarrhea incidence, such that all children in the same household are likely to face similar risk factors in contracting diarrhea. In our first causal model, the first equation that determines the proportion of under-5 children with diarrhea identifies the determining factors, with the treated water as the key causal factor. In second causal model, the first equation that determines the probability of treated water the proportion of children below five years old with diarrhea also appears among the possible explanatory variables. In both causal models, we account for the endogenous regressors.

We estimate the two-equation causal models using the sub-sample of households from the 1998, 2003 and 2008 rounds of the National Demographic and Health Survey (NDHS). Our results show that the treatment of drinking water, controlling for quality of water source and sanitation facility and other factors, reduces the proportion of under-5 children in the household with diarrhea. Moreover, a percentage point increase in the proportion of under-5 children with diarrhea, controlling for other factors such as mother and father characteristics, increases the likelihood that households will sterilize their drinking water. We show that ignoring the simultaneity between diarrhea incidence and treatment of drinking water could lead to a misleading result that the treatment of drinking water increases the incidence of child diarrhea. These results underscore the need to insure the safety of drinking water at the point of use.

II. Data and Methods

Data

Arguably, the incidence and treatment of child diarrhea incidence is strongly influenced by environmental and behavioral factors such as the type of water source or toilet facility, hand washing and the sterilization of drinking water. The same set of environmental and behavioral risk factors are likely to affect not only the child that has diarrhea but all siblings living in the same household. The decision to treat drinking water also tends to be made at the household level as parents are likely to sterilize their drinking water for the benefit of all children rather than just for the afflicted child. In view of these considerations, the unit of analysis in this paper will be the household rather than the individual child. Specifically, we use the proportion of under-5 children in the household who had diarrhea and the household decision to treat drinking water as the endogenous variables of analysis.

We generate a sub-sample of more than 13,500 households with children below five years old from the Philippine NDHS[1] rounds of 1998, 2003 and 2008. This sub-sample comprises about 34-39 percent of the total sample households in each survey year (Table 1). In each NDHS round, at least 73 percent of households had access to improved sources of drinking water, at least 57 percent of households had their own improved sanitation facilities, and at least 37 percent of households treated their drinking water.[2] These percentages suggest that many households with access to improved source still sterilize their drinking water, perhaps to prevent or control diarrhea or other gastrointestinal diseases. The average number of under-5 children per household range from around 1.6 to 1.8. Of these children, between 9 and 11 percent had diarrhea during the two weeks preceding the survey.

[Insert Table 1 around here.]

Table 2 shows the descriptive statistics of the regression variables. The dependent variable for the diarrhea incidence equation is the *proportion of under-5 children with diarrhea* defined as the proportion of children below 5 years old in the household that had diarrhea in the past two weeks. On the average, 9 percent of under-5 children in a household have diarrhea during the reference period. The dependent variable in the treatment of drinking water equation is *treated water*. This binary variable has a value of 1 if the household sterilized its drinking water using

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[1] The NDHS datasets are obtained from ICF Macro (http://www.measuredhs.com).

[2] Following the standards of the WHO/UNICEF (2010), improved water supply include piped water, tube well, protected well, protected spring, rainwater, tanker truck or cart with small tank, and improved toilet facilities include own flush toilets (connected to piped sewer system, septic tank, pit latrine), pit latrine (ventilated, improved, with slab, closed pit) or composting toilet. The acceptable treatment methods for drinking water include boiling, filtering, bleaching, adding chlorine, or solar disinfection (UNICEF/WHO, 2009). The NDHS includes "letting it stand and settle" as an additional treatment method.

any acceptable treatment method and 0 otherwise. On the average, 38 percent of sample households treated their drinking water.

[Insert Table 2 around here.]

The covariates include binary indicators of access to improved water supply (*improved water source*) or sanitation facility (*improved toilet facility*), socioeconomic status as indexed by wealth quintiles (*wealth quintile2*, *wealth quintile3*, *wealth quintile4*, *wealth quintile5*), urban location (*If urban*) and region of residence (17 administrative regions), and the total minutes it takes the household to fetch drinking water from its main source (*time to water source*). On the average, around 81 percent and 69 percent of the households had access to improved water sources and improved toilet facilities, respectively. The mean distance from water source is around 6 minutes. About 49 percent live in urban areas.

Other covariates refer to parental characteristics, such as the binary indicators for the mother's employment status (*if mother is employed*), age in years (*mother's age*) and completion of secondary education (*if mother finished high school*), father's completion of secondary education (*if father finished high school*), and gender of the household head (*if household head is male*). Most household heads are males (92 percent). Less than half of the mothers or fathers finished high school. Household composition is indicated by the share of under-5 children in the total household members (*share of under-5 children in the household*). These children comprise nearly a third of all household members. Last, dummy variables for the years 1998 and 2008 (*Year 1998* and *Year 2008*, respectively) are introduced to account for unobserved time-varying factors.

Estimation strategy

To tease out the causal links between the treated water and the incidence of child diarrhea, we specify two-equation non-recursive models. The first model is a treatment effects model, where the treatment of drinking water appears as regressor in the diarrhea incidence equation. The second model is the instrumental-variable probit model the diarrhea incidence appears as a regressor in the treatment of water equation.

Adapting the treatment effects model in Greene (2008, pp. 889-890), we assume that the proportion of under-5 children with diarrhea (*D*) in the *j*th household is influenced by whether the household treated or not its drinking water (*T*) and a vector of other covariates (***X***), as follows:

$$D_j = \delta T_j + \boldsymbol{X_j}\boldsymbol{\beta} + \varepsilon_j,$$

$$T_j = \boldsymbol{Z_j}\boldsymbol{\theta} + \mu_{j,} \qquad (1)$$

$$T_j = \begin{cases} 1 \text{ if } T^* > 0 \\ 0 \text{ otherwise,} \end{cases}$$

where *j* is the *j*th household, ***Z*** is a vector of variables that influence the household decision to treat drinking water, and δ, $\boldsymbol{\beta}$ and $\boldsymbol{\theta}$ are regression parameters. The errors terms μ and ε are assumed to be bivariate normal with zero mean and covariance matrix $\begin{bmatrix} \sigma^2 & \rho\sigma \\ \rho\sigma & 1 \end{bmatrix}$. The treatment effect is thus δ for those households who were induced to treat their water for reasons other than the incidence of diarrhea in its young members.

We also show the bias arising from ignoring the possible endogeneity in the decision to treat drinking water and using ordinary least squares (OLS) to estimate the diarrhea incidence equation. Referring to this as the naive model, we show that the bias could be substantial and yield counterintuitive results.

To assess the impact of diarrhea incidence on the household's decision to sterilize their drinking water, we adapt the instrumental-variable probit model with endogeneous regressors from Wooldridge (2002, pp. 472-477), i.e.

$$T_j = \alpha D_j + \boldsymbol{Y_j \omega} + \vartheta_j,$$
$$D_j = \boldsymbol{Y_j \pi_1} + \boldsymbol{H_j \pi_2} + \epsilon_{j,} \qquad (2)$$
$$T_j = \begin{cases} 1 & if\ T^* > 0 \\ 0 & if\ T^* \leq 0, \end{cases}$$

where *T*, *D* and *j* are as defined previously, $\boldsymbol{Y}$ is a vector of covariates, $\boldsymbol{H}$ is a vector of instrumental variables, the parameters α, $\boldsymbol{\omega}$, $\boldsymbol{\pi}$'s are regression coefficients (vectors in bold), and ϑ_j and ϵ_j are error terms. In this case, (ϑ_j, ϵ_j) is assumed to have a bivariate normal distribution with zero mean and independent of $\boldsymbol{Y}$ and $\boldsymbol{H}$. In this instrumental variable probit model, the parameter α measures the effect of the incidence of child diarrhea on the decision to treat drinking water in households with the characteristics indicated by the instrumental variables. In both the treatment effects and instrumental-variable probit models, we account for the simultaneity by looking for identifying variables in the instrumental equations e.g., selection equation in the treatment effects model (Equation 1).

In the specification of Equations 1 and 2, we assume that parents' characteristics, the household's socioeconomic status and composition directly affect the decision to treat drinking water. We further assume that these variables identify *treated water* in the right-hand side of the diarrhea incidence equation (Equation 1). In contrast, the incidence of diarrhea is directly influenced by structural variables, specifically, access to water and sanitation facilities. These variables in turn are used as identifying variables for diarrhea incidence in the treatment of drinking water equation (Equation 2).

III. Results

Naïve model

We refer to the results in Table 3 to show the inadequacy of using OLS methods to estimate the diarrhea incidence equation. The estimates under the column "naive model" are obtained by regressing *the proportion of under-5 children with diarrhea* against *treated water, improved water source*, *improved toilet facility* and other control variables. The estimated coefficient of *treated water* is 0.0165 and highly statistically significant (p<0.01). This result is counterintuitive since it suggests that sterilizing drinking water leads to an increase in the incidence of diarrhea! The result however can be explained by the possible simultaneity in the determination of the *proportion of under-5 children with diarrhea* and *treated water* variables. In the presence of simultaneity, the observed positive effect could be the net result of two opposing stimuli. On the one hand, the incidence of diarrhea could induce households to sterilize drinking water i.e., positive correlation between the incidence of diarrhea and the treatment of drinking water. On the other hand, the treatment of drinking water could lead to a reduction in the incidence of diarrhea i.e., a negative correlation between the incidence of diarrhea and the treatment of drinking water. Thus, the observed positive coefficient in the naïve model could mean that the first stimulus dominates the second stimulus.

[Insert Table 3 around here.]

We evaluate the endogeneity of treated water in the naive model by performing the Durbin-Wu-Hausman test. We implement this test by obtaining the residuals from a regression of *treated water* against all predetermined variables in the two-equation causal model (Equation 1) and including these residuals in the regression of the naive model (see "Endogeneity test" column in Table 3). The coefficient of the variable ***Residuals*** is positive and highly statistically significant (p<0.01), indicating that *treated water* is endogenous in the diarrhea incidence equation (Wooldridge, 2002).

The biased OLS estimates thus provide the motivation for estimating a non-recursive two-equation model of diarrhea incidence and treatment of drinking water.

Treatment effects of treated water

Table 4 shows the estimates using the treatment effects model (Equation 1). In this model, we estimated the impact of *treated water* on the *proportion of under-5 children with diarrhea*, accounting for the endogeneity of the former using mother, father and household characteristics (wealth quintiles, share of under-5 children) as identifying variables in the first-stage instrumental equation. The last two columns of Table 4 show the marginal effects (or the marginal probabilities) due to unit change in each of the regressors on the *proportion of under-5 children with diarrhea*. The marginal effects of treated water is negative and highly statistically significant (p<0.01), which implies that households that sterilized their drinking water using any of the acceptable methods were able to reduce the proportion of under-5 children with diarrhea by 5.24 percentage points.

[Insert Table 4 around here.]

Compared to the *treated water*, *improved toilet facility* has a smaller impact, reducing the proportion of under-5 children with diarrhea by 1.22 percentage points (significant at p<0.05). In contrast, *improved water supply* shows no direct impact on child diarrhea (estimated marginal effect is -0.0084, but not statistically significant). Also, each minute spent to fetch drinking water increases by 0.05 percent the proportion of under-5 children with diarrhea (significant at p<0.01).

There appears to be both urban-rural and regional differences in the household-level incidence of child diarrhea. Relative to the diarrhea incidence in the National Capital Region, the situation appears to be worse in the Western Visayas (0.0324), Cordillera Administrative Region (0.0472) and better in Central Visayas (-0.0121), Zamboanga Peninsula (-0.0251) and Northern Mindanao (-0.0101). The proportion of under-5 children with diarrhea is also lower both in 1998 (-0.0317, significant at p<0.01) and 2008 (-0.0181, significant at p<0.01) than in 2003.

In the bottom row of Table 4, the Wald χ^2-statistic is 24.85 and is highly significant (p<0.001). This implies the rejection of the null hypothesis of independence between the *proportion of under-5 children with diarrhea* equation and the instrumental *treated water* equation. This lends further credence to the use of the treatment effects to deal with the endogeneity of treated water in the regression of the proportion of under-5 children with diarrhea.

Following Greene (2008, p. 890), we also compute for the bias of ignoring simultaneity in the use of OLS methods to estimate the effect of treating drinking water on diarrhea incidence. Here, we decompose the differences in the expected proportion of under-5 children with diarrhea between households that treat and do not treat drinking water, as follows:, $E(D|T=1) - E(D|T=0) = \delta + \rho\sigma[\varphi(.)/\Phi(.)\{1-\Phi(.)\}]$. [3] The first term δ (=-0.0426) represents the independent marginal effect of treated water estimated from the treatment effects model of diarrhea in under-5 children, while the second term $\rho\sigma$[...] can be interpreted as a bias term due to the endogeneity of treated water. Calculating the second term using the estimates of ρ, σ and the linear prediction of the treatment equation yields an estimate of 0.0614. The difference in the

[3] φ is the standard normal density, Φ is the standard normal cumulative density function, ρ is the correlation between the error terms (in the treatment effects model), and σ is the standard deviation of the error term of the first equation in the treatment effects model.

expected proportion of child diarrhea is equal to 0.0188, which approximates the coefficient of treated water (0.0179) in the naïve OLS regression.

Effects of diarrhea on the decision to treat water

Table 5 presents the instrumental-variable probit regression of treated water (Equation 2) and the associated marginal effects. The estimated marginal effects indicate that a percent increase in the proportion of under-5 children with diarrhea increases the probability of treated water by 1.2457 percentage points (at $p<0.01$). This confirms our hypothesis that the incidence of diarrhea among under-5 children induces households to treat their drinking water regardless of the source of drinking water.

[Insert Table 5around here.]

As in the specification of the instrumental equation in the estimation of treatment effects model (Table 4), we likewise specify here that parental characteristics, household socioeconomic status and incidence of diarrhea among under-5 children have a direct impact on the household decision to treat drinking water. The likelihood of *treated water* is higher by: 0.28 percentage points for each year of mother's age (at $p<0.01$), 1.21 percentage points if the mother finished at least high school (at $p<0.1$), 1.63 percentage points if the father finished at least high school (at $p<0.05$), and 2.02 percentage points if the household head is male (at $p<0.1$). Interestingly, the probability of *treated water* likewise increase by 6.42 percentage points for each percent increase in the proportion of under-5 children in the household ($p<0.01$), which suggests that households treat water for all children rather than just for those with diarrhea Finally, all households from the second to the fifth wealth quintiles appear to be more likely to treat their drinking water than those in the first wealth quintile (poorest).

Here, we also perform a test of independence of equations in the instrumental-variable probit regression of treated water. As shown in the bottom row of Table 5, the Wald χ^2-statistic is 199.05 and is significant at $p<0.01$. This allows us to reject the null hypothesis of independence between the *treated water* equation and the instrumental *proportion of under-5 children with diarrhea* instrumental equation.

IV. Discussion and Conclusions

Our estimates confirm the simultaneity between the household's decision to treat their drinking water and the incidence of diarrhea in under-5 children in the Philippines. Ignoring this two-way causal relationship yields the misleading finding that water treatment aggravates the incidence of diarrhea by nearly 1.7 percentage points. This seeming positive effect of treated water on diarrhea incidence contradicts previous findings in developing countries (Gundry, Wright and Conroy, 2004; Arnold and Colford, 2007). However, other reviews on the beneficial effects of water treatment cite possible bias in existing studies and the need for longer, blinded controlled trials to justify the scaling up of household water treatment interventions (Luby et al. 2004; Schmidt and Caincross, 2009). Moreover, others contend that the most cost-effective intervention may vary across countries (e.g., Kremer and Zwame, 2007).

While randomized controlled studies are desired, often only observational data are available to guide policy, as in the Philippines. Here we addressed the simultaneity bias from using observational data by linking the household-level, rather than the individual-level, incidence of diarrhea in under-5 children to the household decision to treat drinking water. We find that the treatment of drinking water reduces by 5.2 percent the proportion of under-5 children in a household with diarrhea, controlling for other factors. We also find that a percentage point rise in the proportion of under-5 children with diarrhea lead to a 1.25-percentage points increase in the probability of water treatment, regardless of sources of drinking water and type of sanitation facility.

Thus, our evidence support the proposal to promote household water treatment to improve child health, especially in developing countries where stakes to control diarrheal diseases remain high. In 2008, it accounted for 16 percent of the 3.7 million deaths among children below five years old in African and Southeast Asian countries alone (WHO, 2011). In the Philippines, statistics from the Department of Health show that diarrheal diseases remain among the top ten causes of child morbidity and mortality. The policy implication of our results is that the Philippines stands a greater chance of achieving its Millennium Development Goal target of reducing by half the child mortality rate by 2015 by securing the quality of drinking water at the point of use as it endeavors as well to expand the proportion of population with access to safe drinking water and basic sanitation facilities.

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Table 1. Sample of households with children below 5 years old*, 1998, 2003 and 2008

Sample households	1998	2003	2008	Total
Total households	4,866	4,602	4,318	13,786
with improved water supply	4,076	3,880	3,163	11,119
with improved toilet facilities	2,761	2,953	3,466	9,180
that treat water for drinking	1,230	2,239	1,610	5,079
Average number of under-5 children	1.765	1.668	1.599	1.681
Average proportion of under-5 children with diarrhea	8.2%	11.2%	8.95%	9.4%

*Sample of under-5 children limited to dejure members of households.
Source: National Demographic and Health Survey (various rounds). Authors' calculations.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Proportion of under-5 children with diarrhea	13,593	0.0932	0.2676	0	1
Treated water	13,593	0.3849	0.4866	0	1
Improved water source	13,593	0.8083	0.3937	0	1
Improved toilet facility	13,593	0.6931	0.4612	0	1
Time to water source	13,593	5.9756	17.1065	0	360
Mother's age (in years)	13,593	30.3017	6.7374	15	49
If mother is employed	13,593	0.4544	0.4979	0	1
If mother finished high school	13,593	0.4335	0.4956	0	1
If father finished high school	13,593	0.2751	0.4466	0	1
If household head is male	13,593	0.9165	0.2766	0	1
Share of under-5 children in the household	13,593	0.2982	0.1316	0.05	0.8
If urban	13,593	0.4885	0.4999	0	1
Wealth quintile 2 (lower middle)	13,593	0.1813	0.3853	0	1
Wealth quintile 3 (middle)	13,593	0.2087	0.4064	0	1
Wealth quintile 4 (upper middle)	13,593	0.2030	0.4022	0	1
Wealth quintile 5 (richest)	13,593	0.1701	0.3758	0	1
Ilocos Region	13,593	0.0464	0.2104	0	1
Cagayan Region	13,593	0.0349	0.1836	0	1
Central Luzon Region	13,593	0.1022	0.3030	0	1
Bicol Region	13,593	0.0619	0.2409	0	1
Western Visayas Region	13,593	0.0730	0.2601	0	1
Central Visayas Region	13,593	0.0741	0.2619	0	1
Eastern Visayas Region	13,593	0.0479	0.2136	0	1
Zamboanga Peninsula	13,593	0.0406	0.1974	0	1
Northern Mindanao Region	13,593	0.0470	0.2116	0	1
Davao Region	13,593	0.0467	0.2109	0	1
SOCCSKSARGEN Region	13,593	0.0443	0.2058	0	1
Cordillera Administrative Region	13,593	0.0172	0.1300	0	1
Autonomous Region of Muslim Mindanao	13,593	0.0404	0.1970	0	1
CARAGA Region	13,593	0.0271	0.1624	0	1
CALABARZON Region	13,593	0.1208	0.3259	0	1
MIMAROPA Region	13,593	0.0315	0.1746	0	1
Year 1998	13,593	0.3457	0.4756	0	1
Year 2008	13,593	0.3176	0.4658	0	1

Table 3. OLS Estimates: Determinants of the proportion of under-5 children with diarrhea

Independent variables	Dependent variable = *proportion of under-5 children with diarrhea*			
	Naive model		Endogeneity test	
	Coefficient	Robust standard errors	Coefficient	Robust standard errors
Treated water	0.0165***	0.005	-0.2199***	0.060
Improved water source	-0.0081	0.007	0.0357***	0.013
Improved toilet facility	-0.0145***	0.006	-0.0107*	0.006
Time to water source	0.0005***	0.0002	0.0006***	0.0002
Residual			***0.2389****	***0.061***
If urban	0.0014	0.006	0.0059	0.006
Ilocos Region	0.0205	0.014	-0.04272**	0.021
Cagayan Region	0.0017	0.013	-0.0447***	0.018
Central Luzon Region	0.0107	0.012	-0.0542***	0.021
Bicol Region	-0.0088	0.012	-0.0101	0.012
Western Visayas Region	0.0339***	0.013	0.0516***	0.014
Central Visayas Region	-0.0108	0.012	-0.0851***	0.022
Eastern Visayas Region	0.0260**	0.013	-0.0254	0.019
Zamboanga Peninsula	-0.0228*	0.012	-0.0614***	0.016
Northern Mindanao Region	-0.0072	0.012	-0.0698***	0.020
Davao Region	0.0055	0.013	-0.0741***	0.024
SOCCSKSARGEN Region	0.0344***	0.013	-0.0554**	0.027
Cordillera Administrative Region	0.0496***	0.015	0.0311*	0.016
Autonomous Region of Muslim Mindanao	0.0047	0.013	-0.0287*	0.016
CARAGA Region	0.0018	0.013	-0.0393**	0.017
CALABARZON Region	0.0045	0.011	-0.0233*	0.013
MIMAROPA Region	0.0300*	0.016	0.0000	0.018
Year 1998	-0.0316***	0.006	-0.0780***	0.013
Year 2008	-0.0163***	0.007	-0.0399***	0.009
Constant	0.1080***	0.012	0.2194***	0.031
Number of observations	13,653		13593	
F-stat	5.29		5.62	
Prob>*F*	0.00		0.00	
R-squared	0.009		0.010	

***p<0.01, **p<0.05. *p<0.10.

Table 4. Treatment effects model: Determinants of proportion of under-5 children with diarrhea

Independent variables	Coefficient	Standard errors	*dy/dx*[a]	Standard errors
Dep. var. = proportion of under-5 children with diarrhea				
Treated water	-0.0524***	0.015	-0.0524***	0.015
Improved water source	-0.0084	0.007	-0.0084	0.007
Improved toilet facility	-0.0122**	0.006	-0.0122**	0.006
Time to water source	0.0005***	0.000	0.0005***	0.0001
If urban	0.0028	0.006	0.0028	0.006
Ilocos Region	0.0202	0.014	0.0202	0.014
Cagayan Region	0.0009	0.013	0.0009	0.013
Central Luzon Region	0.0088	0.012	0.0088	0.012
Bicol Region	-0.0118	0.012	-0.0118	0.012
Western Visayas Region	0.0324**	0.013	0.0324**	0.013
Central Visayas Region	-0.0121	0.012	-0.0121	0.012
Eastern Visayas Region	0.0240*	0.013	0.0240*	0.013
Zamboanga Peninsula	-0.0251**	0.012	-0.0251**	0.012
Northern Mindanao Region	-0.0101	0.012	-0.0101	0.012
Davao Region	0.0042	0.013	0.0042	0.013
SOCCSKSARGEN Region	0.0322**	0.014	0.0322**	0.014
Cordillera Administrative Region	0.0472***	0.015	0.0472***	0.015
Autonomous Region of Muslim Mindanao	0.0032	0.013	0.0032	0.013
CARAGA Region	-0.0003	0.013	-0.0003	0.013
CALABARZON Region	0.0038	0.011	0.0038	0.011
MIMAROPA Region	0.0286*	0.016	0.0286*	0.026
Year 1998	-0.0317***	0.006	-0.0317***	0.006
Year 2008	-0.0181***	0.007	-0.0181***	0.007
Constant	0.1349***	0.013		
Dep. var. = treated water				
Wealth quintile 2 (lower middle)	0.1526***	0.035		
Wealth quintile 3 (middle)	0.1209***	0.037		
Wealth quintile 4 (upper middle)	0.0900**	0.040		
Wealth quintile 5 (richest)	0.1481***	0.046		
Mother's age (in years)	0.0027	0.002		
If mother is employed	0.0551**	0.025		
If mother finished high school	0.2137***	0.028		
If father finished high school	0.0652**	0.032		
If household head is male	0.0243	0.044		
Share of under-5 children in the household	0.4408***	0.097		
Constant	-0.7639***	0.088		
Number of observations	13,593			
Wald χ^2	108.57			
Prob> χ^2	0.00			
Log pseudolikelihood	-9.878e+09			
Wald test of independent equations				
χ^2	24.85			
Prob> χ^2	0.00			

[a]marginal probabilities.
***p<0.01, **p<0.05. *p<0.10.

Table 5. Instrumental-variable probit model: Determinants of probability to treat water

Independent variables	Coefficient	Standard errors	dy/dx^a	Standard errors
Dep. var. = treated water				
Proportion of under-5 children with diarrhea	3.7459***	0.045	1.2457***	0.017
Wealth quintile 2 (lower middle)	0.0397	0.028	0.0129	0.009
Wealth quintile 3 (middle)	0.1207***	0.027	0.0399***	0.009
Wealth quintile 4 (upper middle)	0.1257***	0.029	0.0416***	0.010
Wealth quintile 5 (richest)	0.1579***	0.033	0.0525***	0.011
Mother's age (in years)	0.0083***	0.001	0.0028***	0.0004
If mother is employed	-0.0492***	0.018	-0.0163***	0.006
If mother finished high school	0.0363*	0.021	0.0121*	0.007
If father finished high school	0.0488**	0.022	0.0163**	0.008
If household head is male	0.0613*	0.035	0.0202*	0.011
Share of under-5 children in the household	0.1929***	0.068	0.0642***	0.02
Constant	-0.8374***	0.064		
Dep. var. = proportion of under -5 children with diarrhea				
Wealth quintile 2 (lower middle)	-0.0100	0.007		
Wealth quintile 3 (middle)	-0.0318***	0.007		
Wealth quintile 4 (upper middle)	-0.0333***	0.008		
Wealth quintile 5 (richest)	-0.0398***	0.009		
Mother's age (in years)	-0.0022***	0.0004		
If mother is employed	0.0144***	0.005		
If mother finished high school	-0.0055	0.006		
If father finished high school	-0.0114*	0.006		
If household head is male	-0.0153	0.009		
Share of under-5 children in the household	-0.01414**	0.017		
Improved water source	0.0119***	0.003		
Improved toilet facility	-0.0001	0.001		
Time to water source	0.0001***	0.000		
If urban	0.0012*	0.001		
Ilocos Region	-0.0145***	0.003		
Cagayan Region	-0.0091***	0.003		
Central Luzon Region	-0.0148***	0.003		
Bicol Region	0.0031*	0.002		
Western Visayas Region	0.0077***	0.002		
Central Visayas Region	-0.0187***	0.004		
Eastern Visayas Region	-0.0104***	0.003		
Zamboanga Peninsula	-0.0081***	0.002		
Northern Mindanao Region	-0.0149***	0.004		
Davao Region	-0.0202***	0.005		
SOCCSKSARGEN Region	-0.0230***	0.005		
Cordillera Administrative Region	-0.0009	0.002		
Autonomous Region of Muslim Mindanao	-0.0076***	0.002		
CARAGA Region	-0.0083***	0.002		
CALABARZON Region	-0.0050***	0.002		
MIMAROPA Region	-0.0034*	0.002		
Year 1998	-0.0154***	0.003		
Year 2008	-0.0049***	0.001		
Constant	-0.2127***	0.017		
Number of observations	13593			
Wald χ^2	7237.69			
Prob> χ^2	0.00			
Log pseudolikelihood	-9326.0011			
Wald test of independent equations				
χ^2	199.05			
Prob> χ^2	0.000			

[a]marginal probabilities.

***$p<0.01$, **$p<0.05$. *$p<0.10$.