Household treatment of drinking water and child diarrhea: Estimating the effect of each one on the other in the Philippines*

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Abstract

The stakes to control diarrheal diseases remain high. To improve the odds for children, various measures have been proposed, including the treatment of drinking water to secure its quality at the point of use. With only observational data, however, the estimation of the impact must confront the possibility of simultaneity between the treatment of drinking water and the incidence of child diarrhea. To tease out the possible effects of each one on the other, we apply a treatment effects model and an instrumental-variable probit model on sub-sample of households with under-5 children from the National Demographic and Health Surveys. We find that other things being constant the treatment of drinking water reduces by 4.26 percentage points the proportion of under-5 children with diarrhea. Further, for every percentage point increase in the proportion of under-5 children with diarrhea, the probability increases by 0.9616 that a family will its drinking water, other things being constant. These results suggest the need to ascertain at the point of use the quality of water, even those from presumably safe sources, to improve child health.

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1. INTRODUCTION

The stakes to control diarrheal diseases remain high. In 2008, it accounted for 16 percent of the 3.7 million deaths among childen below five years old in African and Southeast Asian countries alone (World Health Organization, 2011). To improve the odds for children, various measures have been adopted to widen access to water and sanitation infrastructures, improve the quality of drinking water at the point of use or promote desired hygiene practices. While among these sanitation and water quality interventions are found to be more effective (e.g., Gunther and Fink, 2010; Fewtrell et al, 2005; Waddington et al., 2009), the most cost-effective intervention could be country-specific (Kremer and Zwame, 2007).

In this paper, we estimate the impact of treatment of drinking water on the incidence of child diarrhea in the Philippines where diarrhea continues to be among the top causes of child mortality and morbidity (Department of Health, 2007). In addition, many Filipino households who have access to piped or other improved sources of drinking water still boil, filter or add chlorine to their water. Presumably, for these households needed to treat their water due to the occurrence of diarrhea in their members. For other households, the access to safe water sources may have been enough to prevent diarrhea. With only observational data available, however, the impact estimation must confront the possible simultaneity between the incidence of child diarrhea and the decision to treat drinking water. Applying treatment effects model and instrumental-variable probit model on a sub-sample of households from the National Demographic and Health Surveys, treated water isfound to reduce the household-level incidence of child diarrhea. Further, the incidence of diarrhea induced at least some households to treat their drinking water. Thus, ignoring the simultaneity could lead to an onerous finding that the treated water increases the incidence of child diarrhea.

2. METHODS

2.1 Data

We culled our sample of around 13,700 households with children below five years old from the Philippines National Demographic and Health Surveys (NDHS)[1] conducted in 1998, 2003 and 2008. The sub-sample of households comprise about 34-39 percent of the total samples in each survey year (Table 1). Of these households, nearly 81 percent had access to improved sources of water for drinking, 67 percent had their own improved sanitation facilities, and 37 percent treated their drinking water.[2] These percentages suggest that some households with improved source still sterilize their drinking water, perhaps to prevent or control diarrhea in their children.The average number of under-5 children per household range from 1.6 to 1.77. Between 9 and 11 percent of the under-5 children had diarrhea during the two weeks preceding the survey.

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

	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.

[1] The NDHS datasets are obtained from ICF Macro (http://www.measuredhs.com).
[2] Following standards of the World Health Organization (2002), improved water suply encompasses piped water, tube well, protected well, protected spring, rainwater, tanker truck or cart with small tank, and improved toilet facilities encompasses own flush toilets (connected to piped sewer system, septic tank, pit latrine), pit latrine (ventilated, improved, with slab, closed pit) or composting toilet. Acceptable treament methods for drinking water include boiling, filtering, bleaching, adding chlorine, letting it stand and settle, or putting it out under the sun.

Table 2 shows the descriptives statistics of the regression variables. The main dependent variable is *children with diarrhea* defined as the proportion of under-5 children with watery stools in each household. The transformation from child-level to household-level incidence of child diarrhea facilitates the estimation of the impact.[3] Futher, the household is more likely to treat water, which is costly, when diarrhea afflicts its members than when it afflicts the general population, besides the scale economies from joint consumption of treated water. The endogenous binary regressor is *treated water*, which takes on a value of 1 if the household sterilized its drinking water and 0 if it did not. The covariates include binary indicators of access to improved water supply (improved water source) or sanitation (improved toilet facility), socioeconomic status (wealth quintiles), urban and region of residence (17 administrative regions), and total minutes it takes the household takes to fetch drinking water from its main source and back (time to water source).

Other covariates refer to parental characteristics, such as the binary indicators for the mother's employment status (if mother is employed) and educational attainment (if mother finished high school), father's educational attainment (if father finished high school), and gender of the household head (male). Household composition is indicated by the share of under-5 children in the total household members. Last, two dummy variables for 1998 and 2008 are introduced to account for unobserved time-varying factors.

[3] Alternative estimation methods include the application of non-recursive bivariate probit and propensity score matching models on a sample of under-5 children. Initial attempts to apply non-recursive bivariate probit using full-information maximum likelihood failed to converge properly due to nonlinearities. On the other hand, the impact estimates using propensity score matching yield higher diarrhea incidence among houseolds that treated their drinking water, possibly due to unobserved heterogeneity. Hence the recourse to household level estimation with the proportion of under-5 children with diarrhea as dependent variable.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
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 (=1 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
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	0.0469	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
National Capital Region	13,593	0.1440	0.3511	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 (=1 if year is 1998)	13,593	0.3457	0.4756	0	1
Year 2008 (=1 if year is 2008)	13,593	0.3176	0.4658	0	1

2.2 Estimation strategy

To tease out the causal effects between treated water and the incidence of child diarrhea, we apply treatment effects model and probit model with an endogenous regressor on the data. Adopting the treatment effects model in Greene (2008), we assume that the proportion of under-5 children with diarrhea (D) in the jth household is influenced by whether the household treated or not its drinking water (T) and a vector of other covariates ($\boldsymbol{X}$), as follows:

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

$$T_j = \boldsymbol{Z}_j \boldsymbol{\theta} + \mu_j,$$

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

where j is the jth household, $\boldsymbol{Z}$ 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.

To assess the effect of the occurrence of child diarrhea on the household's decision to sterilize its drinking water, we adopt the following probit model with an endogeneous regressor estimated using instrumental variables (Wooldridge, 2002)

$$T_j = \alpha D_j + \boldsymbol{Y}_j \boldsymbol{\omega} + \vartheta_j,$$

$$D_j = \boldsymbol{Y}_j \boldsymbol{\pi}_1 + \boldsymbol{H}_j \boldsymbol{\pi}_2 + \epsilon_j,$$

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

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 $\alpha, \boldsymbol{\omega}, \boldsymbol{\pi}$'s are regression coefficients, and ϑ_j and ϵ_j are errort terms. In this case, $(\vartheta_j, \epsilon_j)$ is assumed to have a bivariate normal distribution with zero mean and independent of $\boldsymbol{Y}$ and $\boldsymbol{H}$. In this so-called ivprobit model, the parameter α measures the effect of the incidence of child diarrhea in households with the characteristics indicated by the instrumental variables. Thus, in both the treatement effects and ivprobit models, we handled the possible simultaneity between the incidence of diarrhea and the treatment of drinking water by looking for independent sources of variations in the endogenous regressor. Both models are estmated using STATA 11.

3. RESULTS

3.1 Naïve model

To show how ordinary least squares (OLS) method could be inadequate, we first regressed the proportion of under-5 children with diarrhea against treated water, improved water source, improved toilet facility and other control variables. In Table 3, the estimated coefficient of treated water is 0.0179 and highly statistically significant (p<0.01). Disturbingly, this result suggests that households incur costs to sterilize their drinking water only to have more children with diarrhea! However, the positive effect is possibly the net result of two opposing stimuli. On the one hand, the incidence of diarrhea induces households to sterilize their drinking water. On the other, those who do so are able to prevent or control watery stools. Hence, the positive coefficient could mean that the first stimulus dominates. We show evidence of these stimuli below.

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

	OLS (Dep. var. = *children with diarrhea*)	
Independent variables	Coefficient	Robust standard error
Treated water	0.0179^{***}	0.0055
Improved water source	-0.0089	0.0069
Improved toilet facility	-0.0021	0.0062
Time to water source	0.0004^{**}	0.0002
If urban	0.0096	0.0058
Wealth quintile 2 (lower middle)	-0.0036	0.0081
Wealth quintile 3 (middle)	-0.0304^{***}	0.0082
Wealth quintile 4 (upper middle)	-0.0323^{***}	0.0088
Wealth quintile 5 (richest)	-0.0451^{***}	0.0095
Cagayan Region	-0.0214	0.0153
Central Luzon Region	-0.0075	0.0142
Bicol Region	-0.0352^{**}	0.0141
Western Visayas Region	0.0093	0.0155
Central Visayas Region	-0.0334^{**}	0.0141
Eastern Visayas Region	-0.0005	0.0153
Zamboanga Peninsula	-0.0497^{***}	0.0143
Northern Mindanao Region	-0.0330^{**}	0.0144
Davao Region	-0.0184	0.0154
SOCCSKSARGEN Region	0.0087	0.0159
Cordillera Administrative Region	0.0249	0.0172
National Capital Region	-0.0161	0.0139
Autonomous Region of Muslim Mindanao	-0.0211	0.0153
CARAGA Region	-0.0251^{*}	0.0151
CALABARZON Region	-0.0121	0.0139
MIMAROPA Region	0.0047	0.0177
Year 1998	-0.0296^{***}	0.0060
Year 2008	-0.0180^{***}	0.0065
Constant	0.01392^{***}	0.0146
Number of observations	13595	
F-stat	5.50	
Prob>*F*	0.000	
R-squared	0.0119	

***Significant at the 1% level.
**Significant at the 5% level.
*Significant at the 10% level.

3.2 Treatment effects of treated water

Table 4 shows the marginal effects of the regressors in the treatment effects model and the ivprobit model. In the left half of the table, the marginal effect of treated water is -0.0426, which is highly statistically significant (p<0.001). That is, households that sterilized their drinking water using any of the acceptable methods were able to reduce by 4.26 percent the proportion of under-5 children with watery stools.

In contrast to treated water, access to improved toilet facility lowered the proportion of children with diarrhea by only 1.34 percent (and significant at p<0.05). Access to improved water supply has no direct impact on child diarrhea. Its marginal effect is 0.0043, which is not statistically significant. The same variable, however, has positive coefficient (0.5739) and statistically significant (p<0.001) in the decision to treat equation (second equation in the treatment effects model).[4] In addition, each minute spent to fetch drinking water increases by 0.2 percentage point the proportion of children with diarrhea.

There appears to be both urban-rural and regional differences in the household-level incidence of child diarrhea. Relative to the incidence in the Ilocos Region, it appears to be worse in the Western Visayas (0.0333), Cordillera Administrative Region (0.0388) and better in Central Visayas (-0.0339), Zamboanga Peninsula (-0.0372) and Northern Mindanao (-0.0285). There is also a time trend: the household-level incidence is better in both 1998 (-0.0432) and 2008 (-0.0222) than in 2003.

[4] To save space, the detailed coefficient estimates of all the equations in the treatment effects model and ivprobit model are not shown.They are available from the authors upon request.

Table 4. Determinants of proportion of under-5 children with diarrhea and of the likelihood of treated water

Independent variables	Treatment-effects Model (Dep.var. = *children with diarrhea*)		ivprobit Model (Dep. var. = *treated water)*	
	Marginal effects	Delta-method Standard error	*Marginal effects*	Delta-method Standard error
Treated water[a]	-0.0426***	0.0162		
Children with diarrhea[b]			0.9616***	0.1567
Improved water source	0.0026	0.0069	0.0948***	0.0242
Improved toilet facility	-0.0134**	0.0057		
Time to water source	0.0005***	0.0002		
If urban	0.0020	0.0056		
Mother's age (in years)			0.0020***	0.0006
If mother is employed			-0.0037	0.0084
If mother finished high school			0.0444***	0.0108
If father finished high school			0.0227***	0.0084
If household head is male			0.0233**	0.0116
Share of under-5 children in the household			0.1241***	0.0287
Wealth quintile 2 (lower middle)			0.0125	0.0095
Wealth quintile 3 (middle)			0.0298***	0.0106
Wealth quintile 4 (upper middle)			0.0304***	0.0115
Wealth quintile 5 (richest)			0.0555***	0.0127
Cagayan Region	-0.0144	0.0153	0.0612***	0.0212
Central Luzon Region	-0.0110	0.0142	0.0100	0.0173
Bicol Region	-0.0149	0.0146	0.1762***	0.0424
Western Visayas Region	0.0333**	0.0161	0.1659***	0.0598
Central Visayas Region	-0.0339**	0.0142	0.0042	0.0210
Eastern Visayas Region	0.0084	0.0153	0.0286	0.0211
Zamboanga Peninsula	-0.0372***	0.0143	0.0952***	0.0207
Northern Mindanao Region	-0.0285**	0.0144	0.0325*	0.0187
Davao Region	-0.0192	0.0155	-0.0188	0.0226
SOCCSKSARGEN Region	0.0064	0.0160	-0.0616***	0.0220
Cordillera Administrative Region	0.0388**	0.0173	0.0776*	0.0403
National Capital Region	-0.0041	0.0143	0.1306***	0.0383
Autonomous Region of Muslim Mindanao	-0.0083	0.0152	0.0733**	0.0224
CARAGA Region	-0.0133	0.0150	0.0721***	0.0218
CALABARZON Region	-0.0071	0.0141	0.0858***	0.0267
MIMAROPA Region	0.0183	0.0178	0.0827**	0.0344
Year 1998	-0.0432***	0.0067	-0.0891**	0.0372
Year 2008	-0.0222***	0.0067	-0.0104	0.0170
Number of observations	13,593		13,593	
Wald χ^2	114.05		4527.38	
Prob> χ^2	0.00		0.00	
Log pseudolikelihood	-9.098e+09		-9284.18	
Wald test of independent equations (rho=0): χ^2	16.26			
Wald test of exogeneity (/athro=0): χ^2			9.46	
Prob> χ^2	0.0001		0.0021	

[a]Treated water= *f*(improved water source, mother'age, time to water source, if mother is employed, if mother finished high school, if father finished high school, if household head is male, if urban, share of under-5 children in the household, dummies for wealth quintiles, dummies for regions, dummies for years).

[b]Instrumented variable = proportion of under-5 children with diarrhea; instruments = improved water source, mother'age , time to water source, if mother is employed, if mother finished high school, if father finished high school, if household head is male, if urban, share of under-5 children in the household, dummies for wealth quintiles, dummies for regions, dummies for years.

***Significant at the 1% level.

**Significant at the 5% level.

*Significant at the 10% level.

In the bottom row of Table 4, the Wald χ^2-statistic is 16.26 and is highly significant (p<0.001). Thus, we cannot reject the null hypothesis of independence of the two equations in the treatment effects model. This lends further credibility to the estimated treatment effects of treated water on the household-level incidence of child diarrhea.

3.3. Effects of diarrhea on the decision to treat water

The right half of Table 4 contains the results of the ivprobit estimation. The estimates indicate that incidence of diarrhea increases the probability of treated water by 0.9616 (with p<0.01). This confirms our initial supposition that the incidence of diarrhea in their young members induce households to sterilize their drinking water, even after controlling for the types of water sources.

As in the previous model, we assume here that the parental characteristics and socioeconomic status have their direct impact on the decision to treat drinking water. The likelihood of treated water is higher the older the mother (0.002), if she at least finished high school (0.0444), if the father finished high school (0.0227) and the household head is male (0.0233). The likelihood is also greater in households with high proportion of under-5 children and among the relatively well off (third-fifth wealth quintiles). Relative to the previous results, there is in this case wider regional variation, but less across years.

Of the three unique instruments used in the children with diarrhea equation, only the coefficients of time to water source (0.000451) and urban (0.007) are statistically significant (at p<0.01 and p<0.07, respectively). That of improved toilet facility, while negative at -0.00006, is not. To assess the adequacy of the instruments, the bottom row of Table 4 shows that the Wald χ^2-statistic is 9.46 and significant at p<0.01. Thus, the instruments are adequate to identify the independent causal effect diarrhea incidence on the decision to sterilize drinking water.

4. DISCUSSION AND CONCLUSION

Our results indicate that the observed household-level incidence diarrhea in under-5 children is both a reason for and the result of a decision to treat drinking water in Philippine households. Ignoring this two-way relationship could lead to an onerous result that treated water aggravates the incidence of child diarrhea.

To show the extent of the bias using OLS, we employ the decomposition of the difference in the expected proportion of under-5 children with diarrhea between households that treat and do not treat drinking water described in Greene (2008, p. 890), namely, $E(D|T=1) - E(D|T=0) = \delta + \rho\sigma[\varphi(.)/\Phi(.)\{1-\Phi(.)\}]$. Here, 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 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[5]. The difference in the expected proportion of child diarrhea is equal to 0.0188, which approximates the coefficient of treated water (0.0179) in the naïve OLS regression.

While other studies (e.g., Schmidt and Cairncross, 2008; Arnold and Colford, Jr., 2007), are more cautious about advocating interventions to improve water quality at the point of use there is support here that at least in the Philippines that such interventin can help improve child health. Such intervention appears appropriate to all, regardless of source of drinking water, at least in the interim until leaky pipes are fixed, secure water containers are widely used, or when more adopt better hygiene practices.

[5] 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.

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