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Assessing the Effects of Access to Safe Drinking Water on Children's Nutritional Status in Indonesia

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ABSTRACT

This study analyzed the effects of access to safe drinking water on the nutritional status of children under the age of 59 months in urban and rural areas in Indonesia using the Indonesian Family Life Survey 5. Both piped water and packaged water were considered safe to drink. The descriptive statistics show that children in rural areas typically had insufficient access to safe drinking water and children who consumed safe drinking water had higher short- and long-term nutrition levels. To mitigate selection bias due to the non-random distribution of access to safe drinking water, a matching estimation was used to quantitatively determine the effects of access to safe drinking water on child nutrition. The provision of safe drinking water improved the short- and long-term nutritional status of children in rural areas but had no significant effect to that of children in urban areas. A simulation of this effect on child nutrition shows that in rural areas, improved access to safe drinking water decreases the stunting ratio by 13 percentage points and the wasting ratio by 6.1 percentage points. Additionally, both household income levels and community drinking water prices are important determinants of access to safe drinking water. Therefore, access to safe drinking water is necessary to improve the nutritional status of children in rural Indonesia, and community characteristics contribute to access.

Keywords: child nutrition, water resources, management, rural development, impact evaluation

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INTRODUCTION

The improvement of child nutrition in Indonesia has been slow despite the country's high economic growth. In 2013, 36 percent and 13 percent of children in Indonesia were stunted and wasted, respectively (UNICEF, WHO, and IBRD/WB). Stunting is caused by long-term insufficient nutrient intake and frequent infections (Babu, Gajanan, and Hallam 2017). Stunted children experience learning difficulties at school; consequently, they earn less than their healthy counterparts as adults (UNICEF, WHO, and IBRD/WB). Wasting is usually the result of an acute nutrition shortage (Babu, Gajanan, and Hallam 2017). Wasted children have weakened immune systems and a higher risk of death (WHO 2019). Hence, it is both necessary and critical to improve child nutrition to ensure both children's welfare and sustainable economic growth.

Generally, the nutritional status of children improves as the economy grows because households with higher income invest more in food consumption and effective health care (Haddad et al. 2003). However, the stunting and wasting ratios for children in Indonesia are high even when compared with lower middle-income countries. This shows that in Indonesia, economic growth alone is not enough to improve the nutritional status of children and more direct investments may be needed (De Silva and Sumarto 2018).

Previous research analyzing the factors of child malnutrition in Indonesia has pointed out that the poor quality of drinking water is one of the causes of poor child nutrition (Beal et al. 2018). Securing access to safe drinking water is important for children's growth and health. Inadequate hygiene and sanitation practices can cause chronic bacterial infections, which prevent the body from absorbing nutrition. Undernourished children become wasted in the short term and stunted in the long term. It is particularly important to expand access to safe drinking water in rural areas. Globally, four out of five people have access to piped water in urban areas, while only two out of five people have access to piped water in rural

areas (WHO and UNICEF 2017). To correct this situation, the Sustainable Development Goals (SDGs) include access to safe drinking water for everyone.

Table 1 shows that access to safe drinking water has been expanding in Indonesia because an increasing number of people are using piped or packaged water. However, in 2015, about 17 percent of households still used surface water such as springs, rivers, and ponds as drinking water. Drinking surface water causes infections and diarrhea. Therefore, to improve child nutrition in Indonesia, access to safe drinking water must be ensured.

Patunru (2015) observed that household members who consumed unsanitary drinking water in Indonesia were more likely to have diarrhea. Similarly, by using data from the Indonesia Demographic and Health Surveys in 2007 and 2012, Komarulzaman, Smits, and de Jong (2017) found that children under five years of age who had access to piped water were less likely to have diarrhea. Torlesse et al. (2016) used the 2011 Indonesian cross-sectional survey data to show that children aged 0–23 months were less likely to be malnourished when they consumed safe drinking water. Using the Indonesian Family Life Survey (IFLS), De Silva, and Sumarto (2018) determined that access to drinking water was related to children's height-for-age z-scores even if income levels were controlled. These results confirm that it is necessary to ensure access to safe drinking water to improve the nutritional status of Indonesian children.

In other countries, the quality of drinking water is also important for child nutrition. Jalan and Ravallion (2003) observed that piped water reduced child diarrhea in rural India, although the effects differed based on the mother's characteristics. Using census data from Brazil, Gamper-Rabindran, Khan, and Timmins (2010) found that access to piped drinking water reduced infant mortality rate. Usman, Gerber, and von Braun (2019) used survey data from 2014 to demonstrate that in rural Ethiopia, the incidence of diarrhea decreased when the quality of drinking water improved.

Table 1. Sources of household drinking water in Indonesia

Year	Source (%)				
	Piped Water	Pump Well	Packaged Water	Hand Well	Surface Water
2000	19.0	14.0	1.0	48.0	19.0
2001	18.0	13.0	1.0	47.0	20.0
2002	18.0	14.0	1.0	47.0	19.0
2003	17.0	15.0	2.0	48.0	19.0
2004	18.0	14.0	2.0	47.0	18.0
2005	18.0	14.0	4.0	45.0	19.0
2006	18.0	14.0	4.0	45.0	19.0
2007	16.0	18.0	7.0	40.0	19.0
2008	15.0	17.0	11.0	38.0	19.0
2009	15.0	18.0	13.0	36.0	18.0
2010	12.0	15.0	19.0	35.0	18.0
2011	12.0	15.0	22.0	32.0	18.0
2012	12.0	18.0	39.0	45.0	26.0
2013	11.0	15.0	28.0	28.0	18.0
2014	10.0	16.0	30.0	27.0	18.0
2015	11.0	16.0	30.0	27.0	17.0

Source: Percentage of Household Population by Province and Source of Drinking Water in 2000–2016 (Badan Pusat Statistik 2015)

This study analyzed the impacts of access to safe drinking water on the short- and long-term nutritional status of children under the age of 59 months in urban and rural areas in Indonesia. Common access to safe drinking water has remained inadequate in the country, especially in rural areas. Thus, both urban and rural areas were included in the analysis. To determine the long- and short-term nutritional status of children, the height-for-age z-score and the weight-for-height z-score were used, respectively.

This study differs from previous research in the following aspects. First, the causal effects of access to safe drinking water on children's nutritional status in Indonesia were estimated. Previous studies in Indonesia only pointed out that the quality of drinking water is important as a factor correlated with the nutritional status of children. Past research analyzed the correlation between the incidence of diarrhea or stunting and access to safe drinking water, while the present study quantitatively analyzed the impact

of safe drinking water on the nutritional status of children by using matching estimation. The analysis shows the extent to which children can benefit from safe drinking water. Moreover, to confirm the robustness of the estimation results, an analysis considering the endogeneity of children's nutritional status and access to safe drinking water was performed.

Second, this study considered both piped water and packaged water as safe drinking water. In previous studies, piped water that was boiled before consumption was considered safe drinking water. However, in Indonesia, the rate of purchasing packaged drinking water is increasing, while the rate of using piped water as drinking water is decreasing. This suggests that packaged water plays an important role in access to safe drinking water. Furthermore, in SDG 6.1, which aims to improve access to affordable drinking water, packaged water is considered vital in improving access to safe drinking water.

DATA AND DESCRIPTIVE STATISTICS

The data employed in this study was obtained from the IFLS5 conducted in 2014 (Strauss, Witoelar, and Sikoki 2016). The IFLS is an ongoing longitudinal socio-economic and health survey conducted by RAND, the Center for Population and Policy Studies of the University of Gadjah Mada, and Survey Meter (Strauss, Witoelar, and Sikoki 2016). In the survey, the sampling is stratified for provinces then randomized within the strata. The IFLS5 includes measures of individual health, household composition, labor and non-labor income, schooling, fertility, consumption expenditure, immunization, and community infrastructure. Rural and urban areas are categorized according to the indicators of the Indonesian Bureau of Statistics. These indicators are population density, share of population in agriculture, and quantity of infrastructure such as schools, roads, and markets. Areas that score above a threshold are categorized as urban. This study, in which the sample included children under the age of 59 months, observed 2,302 children (1,073 from rural areas) and 2,059 households. This means that some child data were obtained from the same household. There were 311 communities, defined at the cluster level.

The IFLS5 asked questions about the type of water households used as drinking water. In the present study, access to safe drinking water was assumed when a household purchased drinking water or used piped water as drinking water. According to Komarulzaman, Smits, and de Jong (2017), piped water in Indonesia may also be contaminated by fecal coliform. However, in the available data, 90 percent of the households that used piped water for drinking boiled the water before it was consumed. Therefore, piped water was considered safe drinking water.

Table 2 shows the proportion of drinking water sources in urban and rural areas in Indonesia. Nearly half of the households in urban areas and only 19 percent of households in rural areas purchased water for drinking. Moreover, 15 percent of households in rural areas used piped water for drinking, which means only about one-

Table 2. Sources of household drinking water in urban and rural areas

Source	Urban (%)	Rural (%)
Packaged water	49.4	18.7
Piped water	18.1	14.5
Pump well	24.1	32.4
Hand well	5.5	14.2
Surface water	3.0	20.3
Sample size	1,085	974

Source: Indonesian Family Life Survey 5 (Strauss, Witoelar, and Sikoki 2016)
Note: The sample size is the number of households.

third of households have access to safe drinking water based on the definition used in this study. On the other hand, 3 percent of households in urban areas and 20 percent of households in rural areas drink surface water. These statistics indicate that access to safe drinking water is much lower in rural areas in Indonesia.

This study used height-for-age z-scores and weight-for-height z-scores as indicators of children's nutritional status. They were calculated using the World Health Organization child growth standards (WHO 2006). Height-for-age z-scores represent long-term nutritional deprivation. Children with low height-for-age z-scores may be chronically malnourished. Children are defined as stunted if their height-for-age z-score is more than two standard deviations below the WHO Child Growth Standards median. Similarly, weight-for-height z-scores represent short-term nutritional deprivation. Children with low weight-for-height z-scores may be temporally malnourished. Children are defined as wasted if their weight-for-height z-score is more than two standard deviations below the WHO Child Growth Standards median.

Table 3 shows the descriptive statistics of height-for-age and weight-for-height z-scores in urban and rural areas. In urban areas, height-for-age z-scores were 0.06 standard deviations lower for children without safe drinking water, although the difference was not statistically significant. Furthermore, the stunting ratio was 0.9 percentage points lower for children who consumed safe drinking water. However, in rural areas, height-for-age z-scores were 0.32 standard

Table 3. Child nutritional status in urban and rural areas

Nutritional Status	Urban		Rural	
	Clean	Not Clean	Clean	Not Clean
Height-for-age z-score	-1.24 (1.49)	-1.30 (1.50)	-1.41 (1.38)	-1.73 (1.45)
Stunting (%)	30.0	30.9	32.4	44.8
Weight-for-height z-score	-0.24 (1.54)	-0.28 (1.49)	-0.28 (1.35)	-0.36 (1.42)
Wasting (%)	8.3	9.4	8.3	9.5
Sample size	783	446	336	737

Source: Indonesian Family Life Survey 5 (Strauss, Wittoelar, and Sikoki 2016)

Note: The numbers in parentheses are standard deviation.

deviations lower for children without safe drinking water, and the difference was statistically significant. Moreover, the stunting ratio was 12.4 percentage points lower for children with access to safe drinking water. In urban areas, the weight-for-height z-scores were 0.04 standard deviations higher than those of children without safe drinking water, although the difference was not statistically significant. In rural areas, the weight-for-height z-scores were 0.12 standard deviations higher for children who consumed safe drinking water, and the difference was statistically significant. However, in contrast to the stunting ratio, the difference in the wasting ratio between children with access to safe drinking water and those without in urban and rural areas was almost the same: 1.2 percent and 1.1 percent, respectively. These descriptive statistics suggest that the short- and long-term nutritional status of children with access to safe drinking water tended to be good in rural areas, while the differences in nutritional status were not significant in urban areas, depending on whether there was access to safe drinking water. This implies that access to safe drinking water improves children's nutritional status only in rural areas. However, factors associated with both child nutrition and access to safe drinking water should be considered when estimating the causal effects of access to safe drinking water on child nutrition.

Factors affecting access to safe drinking water were also examined and analyzed which could help in drawing policy implications from the findings of the study. Explanatory variables used in the

model for access to safe drinking water included household head gender, number of household members, child ratio in the household, elderly ratio in the household, availability of electricity in the household, presence of a toilet in the household, home ownership, possession of a television, parent's ability to read the newspaper, parents' education level, log of total consumption per capita, log of price of water in the community, existence of paved roads in the community, presence of a market in the community, and availability of a bus station in the community (indicating transport accessibility). The explanatory variables were chosen following Irianti, Prasetyoputra, and Sasimartoyo (2016), who analyzed the factors correlated with drinking water sources in Indonesia.

Following De Silva and Sumarto (2018) and Titaley et al. (2019), household head gender, number of household members, child ratio in the household, elderly ratio in the household, availability of electricity in the household, presence of a toilet in the household, home ownership, possession of a television, parent's ability to read the newspaper, parents' education level, and log of total consumption per capita were used as explanatory variables for child nutrition.

Child ratio is the ratio of the number of children under the age of 15 years to the total number of household members. Elderly ratio is the ratio of the number of elderly people over the age of 65 years to the total number of household members. Total consumption per capita is the sum of food consumption per month and non-food

consumption divided by the number of family members. It does not include consumption for durable goods. Total consumption per capita was used in lieu of income level of households. The community price of water is expressed per liter.

Table 4 presents the summary statistics. The table shows that in both urban and rural areas, households with access to safe drinking water had higher total consumption per capita. Furthermore, parents' education level was likely to be higher in households with access to safe drinking water. Therefore, it is necessary to consider the differences in these characteristics when comparing the nutritional status of children with or without access to safe drinking water. The mean and standard deviation of the water price for children without safe drinking water was higher in rural areas. This implies that water prices vary by community in rural areas, suggesting that high prices may affect access to safe drinking water.

In Table 3, the height-for-age z-scores of children without access to safe drinking water in urban and rural areas differed by 0.43 standard deviations. Moreover, the stunting ratio was 13.7 percentage points higher in rural areas. Hence, even among children who did not have access to safe drinking water, the nutritional status varied depending on whether they lived in urban or rural areas. Table 4 also shows the differences in household characteristics between urban and rural areas. Toilets were present in 82 percent and 71 percent of households in urban and rural areas, respectively. This difference can lead to a gap between the nutritional status among children in urban and rural areas because improved hygiene is important for child nutrition (Kumar and Vollmer 2013). There was also a difference in the educational levels of parents, especially mothers, which is important for child nutrition (Beal et al. 2018). The educational level of mothers in rural areas was mainly primary or secondary education (approximately 60 percent), while that of mothers in urban areas was high school or college education. A mother's educational level, specifically knowledge on child nutrition and health, is especially important because she is the main caregiver of children. Beal et al.

(2018) pointed out the importance of education based on the results of meta-analysis of previous studies, correlating education of mothers and the nutritional status of children.

METHODS

Matching Estimation

This study analyzed the causal effects of access to safe drinking water on the nutritional status of children as indicated by height-for-age z-scores and weight-for-height z-scores. The major challenge in estimating these causal effects is the non-random distribution of the treatment (i.e., access to safe drinking water). The difference in a child's nutrition, with or without access to drinking water, can be explained by access to safe drinking water as well as other characteristics, such as parents' health knowledge and household income level, which improve access to safe drinking water. Therefore, to estimate the effects of access to safe drinking water on child nutrition accurately, it is necessary to compare the nutritional status of the same child with and without access to safe drinking water. The effect of access to safe drinking water can be expressed as an average treatment effect (ATE). The ATE of the outcome variable is:

$$ATE = E(Y_{1i} - Y_{0i}) \quad (1)$$

where Y_{1i} , Y_{0i} is the nutritional status of child i with and without access to safe drinking water. From equation (1), ATE represents the mean of the difference in the nutritional status of the same child i with and without access to safe drinking water; that is, the effect of access to safe drinking water on the nutritional status of children. However, only one of the realized Y_{0i} or Y_{1i} is usually observed, which means that (1) cannot be estimated directly.

To solve this problem, this study used propensity score matching. This type of matching enables the comparison of Y_i between different observations by searching for a counterfactual

Table 4. Descriptive statistics of household characteristics

Variable	Urban			Rural		
	Clean		Not Clean	Clean		Not Clean
	Mean	Standard Deviation		Mean	Standard Deviation	
Household sex (1 = male)	0.95	0.22	0.94	0.25	0.96	0.19
Household size	4.94	1.79	5.04	1.80	4.60	1.39
Child ratio	0.40	0.13	0.40	0.13	0.42	0.12
Elder ratio	0.03	0.07	0.04	0.08	0.03	0.07
Toilet (1 = yes)	0.83	0.37	0.82	0.39	0.79	0.41
Consumption per capita (IDR per month)	1,201,096	1,161,970	861,152	686,683	1,045,639	938,178
Own house (1 = yes)	0.60	0.49	0.73	0.44	0.78	0.41
Television (1 = yes)	0.96	0.19	0.95	0.23	0.94	0.23
Father cellphone (1 = yes)	0.91	0.28	0.88	0.32	0.89	0.32
Father Internet (1 = yes)	0.49	0.50	0.37	0.48	0.31	0.46
Father elementary school	0.189	0.39	0.24	0.43	0.33	0.47
Father junior high school	0.20	0.40	0.22	0.41	0.28	0.45
Father high school	0.44	0.49	0.39	0.49	0.30	0.46
Father college	0.16	0.37	0.13	0.34	0.09	0.28
Mother cellphone (1 = yes)	0.79	0.41	0.73	0.45	0.72	0.45
Mother Internet (1 = yes)	0.37	0.48	0.30	0.45	0.21	0.41
Mother elementary school	0.19	0.39	0.20	0.40	0.32	0.46
Mother junior high school	0.24	0.42	0.26	0.44	0.32	0.47
Mother high school	0.43	0.49	0.40	0.49	0.24	0.43
Mother college	0.15	0.35	0.13	0.34	0.12	0.32
Price of water (IDR per liter)	4,568	3,817	4,678	4,372	3,626	2,349
Paved road	1.00	0.00	1.00	0.00	0.98	0.14
Market	0.47	0.50	0.46	0.50	0.30	0.46
Bus station	0.29	0.45	0.23	0.42	0.19	0.39
Sample size	675		405		310	664

Source: Indonesian Family Life Survey 5 (Strauss, Witoelar, and Sikoki 2016)

Note: The sample size is the number of households; USD 1 = IDR 12,160 in 2014

with the same attribute as sample i using the propensity score (Jalan and Ravallion 2003). For instance, Kumar and Vollmer (2013) and Jalan and Ravallion (2003) used propensity score matching to estimate the impacts of improved hygiene on child health. Propensity score matching mitigates bias due to confounding factors and eliminates the need to assume a functional form of outcome (e.g., children's nutritional status). The propensity score is defined as the predicted probability of children having access to safe drinking water given covariates:

$$p(\mathbf{x}_i) = \Pr(T_i = 1 | \mathbf{x}_i) \quad (2)$$

where \mathbf{x}_i is a vector of covariates of child i that correlate to access to safe drinking water, T_i is a dummy variable taking a value of 1 if child i has access to safe drinking water and 0 otherwise, and $\Pr()$ indicates probability.

When using matching estimation, the conditional mean independence assumption must be met. This implies treatment exogeneity by restricting the independence between potential outcomes and treatment to the mean once covariates \mathbf{x}_i are fixed. This assumption can be expressed as follows:

$$\begin{aligned} E(Y_{1i} | \mathbf{x}_i, T_i = 1) &= E(Y_{1i} | \mathbf{x}_i, T_i = 0) = E(Y_{1i} | \mathbf{x}_i) \\ E(Y_{0i} | \mathbf{x}_i, T_i = 1) &= E(Y_{0i} | \mathbf{x}_i, T_i = 0) = E(Y_{0i} | \mathbf{x}_i) \end{aligned} \quad (3)$$

Therefore, assumption equation (1) is transformed as follows:

$$\begin{aligned} \text{ATE} &= E(Y_{1i} - Y_{0i}) \\ &= E[E(Y_{1i} | p(\mathbf{x}_i)) - E(Y_{0i} | p(\mathbf{x}_i)) | \mathbf{x}_i] \\ &= E[E(Y_{1i} | p(\mathbf{x}_i), T_i = 1) - E(Y_{0i} | p(\mathbf{x}_i), T_i = 0) | \mathbf{x}_i] \end{aligned} \quad (4)$$

Equation (4) shows that ATE can be estimated by comparing samples with the same propensity score. If matching is successful, the distribution of covariates should be the same between treatment and control groups. This study used standardized mean difference and variance ratio to determine whether the covariates balanced. This is the most

commonly used statistic to examine the balance of covariate distribution (Zhang et al. 2019). The propensity scores were estimated using a logit model.

The other assumption that must be satisfied when using propensity score matching is the overlap assumption (Wooldridge 2010), which states that each child has a positive probability of having access to safe drinking water. To check whether the overlap assumption was violated, this study used the estimated densities of the probability of obtaining each treatment level after matching.

The ATE was estimated using nearest-neighbor matching based on Euclidean distance for the robustness check. The Euclidean distance between observation i and j is defined as:

$$|\mathbf{x}_i - \mathbf{x}_j| = \left[(\mathbf{x}_i - \mathbf{x}_j)' (\mathbf{x}_i - \mathbf{x}_j) \right]^{\frac{1}{2}} \quad (5)$$

Nearest neighbor matching eliminates the need to assume a functional form for the treatment model in addition to the outcome model. This study used exact matches on covariates, home ownership, possession of a television, and availability of a toilet.

Control-Function Approach

A potential disadvantage of matching estimation is the endogeneity problem resulting from the violation of conditional mean independence assumption. The violation of this assumption implies that after controlling for covariates, access to safe drinking water and children's nutritional status correlate because of unobserved components that affect both. This induces the self-selection problem. For instance, children who are likely to benefit from safe drinking water may have access to it. Endogeneity in matching estimation causes a biased estimation of ATE because in equation (4), the second and third lines become inapplicable.

To ensure the robustness of the matching results to the conditional mean independence assumption, the case that this assumption is

not satisfied because of omitted variables was considered. A control-function approach can thus mitigate the endogeneity problem between treatment and outcomes. The models are as follows:

$$Y_{0i} = \mathbf{x}_i \boldsymbol{\beta}_0 + \epsilon_{0i} \quad (6)$$

$$Y_{1i} = \mathbf{x}_i \boldsymbol{\beta}_1 + \epsilon_{1i} \quad (7)$$

$$T_i = \Phi(\mathbf{z}_i \boldsymbol{\pi}) + u_i \quad (8)$$

$$Y_i = T_i Y_{1i} + (1 - T_i) Y_{0i} \quad (9)$$

$$E(\epsilon_{ki} | \mathbf{x}_i, \mathbf{z}_i) = E(\epsilon_{ki} | \mathbf{x}_i) = E(\epsilon_{ki} | \mathbf{z}_i) \\ = 0 \text{ for } k \in \{0, 1\} \quad (10)$$

$$E(\epsilon_{ki} | T_i) \neq 0 \text{ for } k \in \{0, 1\} \quad (11)$$

where Y_{1i} and Y_{0i} are the nutritional status of child i with and without access to safe drinking water, T_i is a dummy variable taking 1 if child i has access to safe drinking water and 0 if otherwise, \mathbf{x}_i is an exogenous variable vector that affects the nutritional status of child i , \mathbf{z}_i is an exogenous variable vector that affects access to safe drinking water, $\Phi()$ denotes the standard normal cumulative distribution, ϵ_{0i} and ϵ_{1i} are disturbances that include unobserved components affecting the nutritional status of child i whose expectation is 0, u_i is a disturbance that includes an unobserved component that affects access to safe drinking water whose expectation is 0, and $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_0$, $\boldsymbol{\pi}$ are parameters. Y_{0i} and Y_{1i} are potential outcomes. In this study, only Y_i was observed. $\boldsymbol{\beta}_1 \neq \boldsymbol{\beta}_0$ implies observable heterogeneity, while $\epsilon_{1i} \neq \epsilon_{0i}$ implies unobservable heterogeneity.

Equation (11) is an important component of the control function approach. This equation states that access to safe drinking water T_i correlated to unobserved factors ϵ_k affects the nutritional status of child i . If equation (11) is met, the conditional mean independence assumptions are violated.

The control function approach uses the correlation of unobserved factors (Wooldridge 2015). Equation (10) states that exogenous variables \mathbf{z}_i do not correlate with ϵ_{ki} . Therefore, from equation (8), the correlation between T_i and ϵ_{ki} arise from the correlation between u_i and ϵ_{ki} . Subsequently, equation (11) becomes:

$$E(\epsilon_{ki} | T_i) = u_i \gamma_k \quad (12)$$

where γ_k expresses correlation between u_i and ϵ_{ki} . ATE can be expressed as:

$$ATE = E(Y_{1i} - Y_{0i}) \\ = E(\mathbf{x}_i \boldsymbol{\beta}_1 - \mathbf{x}_i \boldsymbol{\beta}_0 + u_i \gamma_1 - u_i \gamma_0) \quad (13)$$

However, u_i cannot be observed because it is a disturbance. Hence, the estimation of u_i as residual \hat{u}_i was obtained by estimating equation (8) and using this residual as a regressor to estimate equation (13) (Terza, Basu, and Rathouz 2008). Therefore, the control function approach is a two-step estimation using the residual as a regressor to control for the influence of omitted variables (Cameron and Trivedi 2005). The parameters and residual are estimated simultaneously using the generalized method of moment (GMM) approach.

If γ_1 and γ_0 are 0, access to safe drinking water T_i does not correlate to unobserved factors ϵ_{ki} , which affect children's nutritional status. This means that the conditional mean independence assumption is met. This hypothesis was tested using the Wald test. The null hypothesis tested was:

$$H_0 : \gamma_1 = 0, \gamma_0 = 0$$

If the null hypothesis is rejected, endogeneity is present, and the control function approach should be used to estimate ATE. On the contrary, if the null hypothesis is accepted, the ordinary least squares estimation provides more efficient standard errors (Wooldridge 2010). This is because \hat{u}_i is a function of \mathbf{z}_i , which includes \mathbf{x}_i , and causes multicollinearity.

Table 5. Balance diagnostics of explanatory variables for urban areas

Variable	Standardized Mean Differences			Variance Ratio		
	Before	Propensity Score Matching	Nearest Neighbor Matching	Before	Propensity Score Matching	Nearest Neighbor Matching
Household sex	0.041	0.004	−0.036	0.857	0.987	1.171
Household size	−0.047	0.041	0.005	0.927	1.017	1.013
Child ratio	0.097	−0.043	−0.018	1.043	0.984	1.050
Elder ratio	−0.091	0.023	−0.009	0.828	1.101	1.080
Toilet	0.029	−0.019	–	0.950	1.032	–
Own house	−0.285	−0.041	–	1.209	1.025	–
Television	0.033	0.017	–	0.865	0.925	–
Father cellphone	0.086	0.011	−0.017	0.801	0.973	1.051
Father Internet	0.264	0.064	0.107	1.071	1.016	1.027
Father elementary school	−0.133	−0.088	0.010	0.829	0.890	1.014
Father junior high school	−0.005	0.060	0.021	0.991	1.100	1.033
Father high school	0.060	0.082	0.013	1.018	1.033	1.003
Father college	0.084	−0.061	−0.037	1.178	0.898	0.930
Mother cellphone	0.150	0.008	0.018	0.829	0.990	0.976
Mother Internet	0.173	0.061	0.021	1.126	1.046	1.015
Mother elementary school	−0.028	−0.063	0.023	0.955	0.909	1.039
Mother junior high school	−0.050	0.047	−0.015	0.940	1.063	0.982
Mother high school	0.049	−0.023	0.018	1.015	0.993	1.005
Mother college	0.052	0.036	−0.021	1.111	1.080	0.957
Log of consumption per capita	0.493	−0.067	0.264	1.054	0.875	1.030
Log of price of water	0.029	0.027	0.070	0.794	1.005	0.985
Road	–	–	–	–	–	–
Market	0.030	−0.008	0.038	1.003	0.999	1.008
Bus station	0.118	0.016	0.106	1.140	1.017	1.141

RESULTS AND DISCUSSION

Access to Safe Drinking Water

Tables 5 and 6 report the standardized differences and variance ratio for diagnosing covariate balance between treated and untreated subjects in the before and after matching samples, respectively.

For the urban area sample, the largest absolute standardized difference was for the log of consumption per capita in the unmatched sample (0.493). In contrast, the largest absolute

standardized difference was for the father's elementary school education in the matched sample using propensity score matching (0.088) and the log of consumption per capita in the matched sample using nearest neighbor matching (0.264). The most extreme variance ratio was for electricity in the unmatched sample (1.714), the father's ability to read the newspaper in the matched sample using propensity score matching (1.653), and the father's newspaper reading in the matched sample using nearest neighbor matching (1.707).

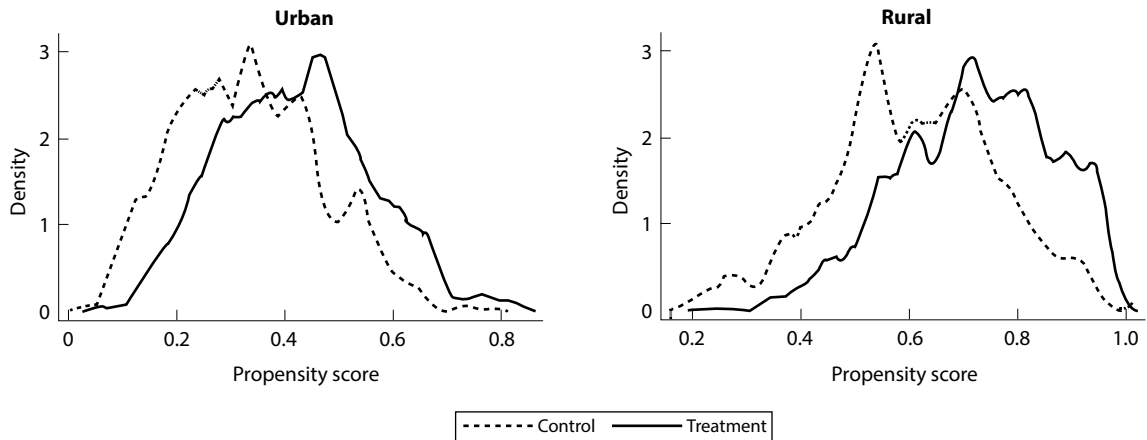
Table 6. Balance diagnostics of explanatory variables for rural areas

Variable	Standardized Mean Differences			Variance Ratio		
	Before	Propensity Score Matching	Nearest Neighbor Matching	Before	Propensity Score Matching	Nearest Neighbor Matching
Household sex	-0.026	0.027	0.011	1.133	0.861	0.937
Household size	-0.109	-0.028	-0.066	0.749	0.867	0.824
Child ratio	0.085	-0.035	0.105	0.775	0.784	0.880
Elder ratio	-0.070	0.042	-0.012	0.825	1.053	0.963
Toilet	0.193	-0.051	-	0.800	1.055	-
Own house	-0.082	-0.007	-	1.132	1.011	-
Television	0.368	-0.005	-	0.386	1.011	-
Father cellphone	0.225	-0.039	-0.023	0.638	1.069	1.043
Father Internet	0.201	0.023	0.068	1.238	1.025	1.085
Father elementary school	-0.012	0.051	0.059	0.993	1.034	1.039
Father junior high school	-0.020	0.029	0.019	0.981	1.030	1.018
Father high school	0.000	-0.043	-0.053	1.001	0.960	0.954
Father college	0.064	-0.059	-0.056	1.220	0.833	0.820
Mother cellphone	0.256	0.055	-0.002	0.841	0.963	1.001
Mother Internet	0.135	-0.041	0.027	1.237	0.935	1.045
Mother elementary school	0.001	-0.021	0.026	1.002	0.980	1.019
Mother junior high school	0.051	0.072	0.010	1.047	1.056	1.009
Mother high school	-0.138	0.014	-0.021	0.868	1.013	0.981
Mother college	0.162	-0.067	0.003	1.542	0.829	1.010
Log of consumption per capita	0.319	-0.007	0.153	1.121	0.976	0.965
Log of price of water	-0.382	-0.019	-0.193	0.657	0.964	0.742
Road	-0.003	0.013	0.000	1.025	0.915	1.000
Market	-0.066	0.010	-0.097	0.949	1.008	0.913
Bus station	0.137	-0.102	0.072	1.285	0.808	1.163

For the rural area sample, the largest absolute standardized difference was for the log of price of water in the unmatched sample (0.382). The largest absolute standardized difference was for the availability of a bus station in the matched sample using propensity score matching (0.102) and the log of price of water in the matched sample using nearest neighbor matching (0.193). The most extreme variance ratio was for electricity in the unmatched sample (0.149), the matched sample using propensity score matching (0.504), and the matched sample using nearest neighbor matching (0.135).

Figure 1 illustrates the probability density distributions of propensity scores for access to safe drinking water. The graphs show the overlapping region of the matching results. In both urban and rural areas, the plots do not indicate excessive probability mass at 0 or 1, and the masses of the estimated densities occur in regions where they overlap with each other. Thus, there is no evidence that the overlap assumption was violated.

Table 7 reports the estimation results of access to safe drinking water by the logit model, from which propensity scores were calculated. The marginal effects were calculated for each

Figure 1. Overlap condition**Table 7. Determinants of access to safe drinking water**

Variable	Urban		Rural	
	Coefficient	Standard Error	Coefficient	Standard Error
Household sex	-0.002	0.057	-0.079	0.076
Household size	0.016**	0.008	-0.018*	0.010
Child ratio	-0.055	0.116	0.194	0.120
Elder ratio	0.032	0.193	0.074	0.197
Electricity	-0.208	0.258	0.222**	0.089
Toilet	-0.020	0.038	0.044	0.033
Own house	-0.123***	0.030	-0.077**	0.037
Television	-0.032	0.067	0.181***	0.036
Father newspaper	-0.110	0.116	0.008	0.081
Father cellphone	0.001	0.047	0.031	0.043
Father Internet	0.100***	0.033	0.057	0.038
Father elementary school	-0.045	0.155	-0.006	0.126
Father junior high school	-0.043	0.156	-0.016	0.128
Father high school	-0.067	0.156	-0.035	0.126
Father college	-0.079	0.161	-0.062	0.125
Mother newspaper	0.003	0.148	-0.153	0.093
Mother cellphone	0.035	0.035	0.046	0.032
Mother Internet	0.005	0.038	-0.019	0.042
Mother elementary school	0.223*	0.136	0.231	0.146
Mother junior high school	0.178	0.138	0.225	0.154
Mother high school	0.182	0.138	0.152	0.156
Mother college	0.153	0.143	0.283	0.173
Log of consumption per capita	0.178***	0.024	0.069***	0.023
Log of price of water	0.025	0.029	-0.169***	0.032
Road	—	—	-0.114	0.115
Market	-0.020	0.028	0.063**	0.030
Bus station	0.048	0.032	0.111***	0.042

Note: ***, **, and * indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively. The marginal effects were calculated by obtaining the average of all household marginal effects.

observation in the sample and the average was obtained.

In urban areas, the variables that positively and significantly correlated with access to safe drinking water were the size of the household, the father's access to the Internet, and the log of consumption per capita. Furthermore, the coefficient on own house was negative and statistically significant. However, other variables were not statistically significant.

In rural areas, electricity, possession of a television, the log of consumption per capita, the presence of a market in the community, and the availability of a bus station in the community were positively and significantly correlated with access to safe drinking water. Conversely, household size, own house, and the log of price of water were negative and statistically significant, while other variables were not statistically significant.

From the estimation results, household size, own house, and income level were important for access to safe drinking water in both urban and rural areas. When the number of family members increased by one, the probability of accessing safe drinking water increased by 2 percentage points in urban areas and decreased by 2 percentage points in rural areas. Own house reduced the probability of access to safe drinking water by 7 percentage points in rural areas and by 12 percentage points in urban areas. This may initially appear counterintuitive if own house is associated with higher income. However, [Irianti, Prasetyoputra and Sasimartoyo](#)

(2016) noted in their study that single-unit houses, which are more likely to be owned, tend to be associated with lower household income. Thus, it is possible that house ownership in the study sample is associated with lower household income.

The marginal effect of the log of consumption per capita was 0.18 percentage points in urban areas and 0.07 percentage points in rural areas. In urban areas, the parents' characteristics affected access to safe drinking water even when the income level was controlled. Access to safe drinking water improved by 10 percentage points when the father had access to the Internet. In rural areas, community variables were related to safe drinking water. When the price of water increased by 1 percent, the probability of accessing safe drinking water decreased by 0.17 percentage points. However, in urban areas, the price of water did not affect access to safe drinking water. Other variables related to market access, such as the presence of a market (6 percentage points) and the availability of a bus station (11 percentage points), increased the probability of accessing safe drinking water.

Average Treatment Effect

Table 8 reports the estimation results of the ATEs for the height-for-age z-score and weight-for-height z-score. For the height-for-age z-score, both the propensity score matching estimation results and the Euclidean distance matching

Table 8. Average treatment effects (matching estimation)

Region	Height-for-Age Z-score		Weight-for-Height Z-score	
	Propensity Score Matching	Nearest Neighbor Matching	Propensity Score Matching	Nearest Neighbor Matching
Rural	0.315*** (0.114)	0.230* (0.136)	0.275** (0.117)	0.146 (0.104)
Sample size	1,073	1,073	1,073	1,073
Urban	0.000 (0.111)	0.136 (0.111)	0.033 (0.103)	0.084 (0.106)
Sample size	1,222	1,222	1,222	1,222

Note: ***, **, and * indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively. The numbers in parentheses are standard errors. The sample size is the number of children.

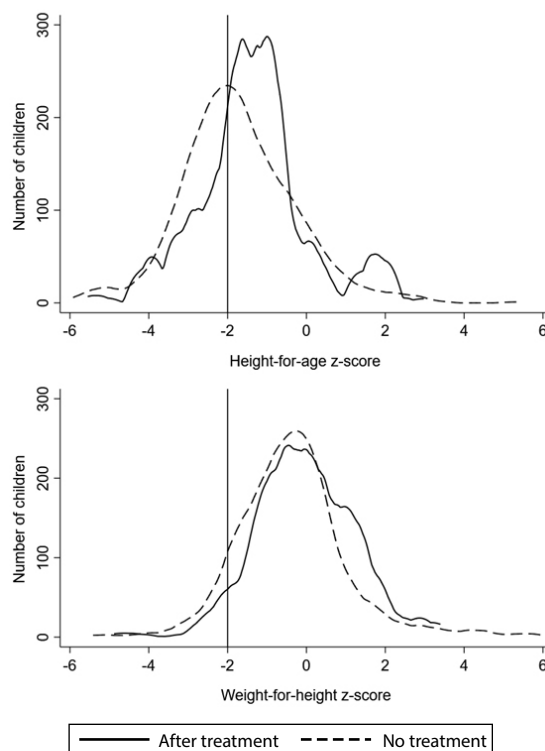
estimation results were only positively significant in rural areas. The results for the two estimation methods show that access to safe drinking water in rural areas increased the height-for-age z-score by 0.315 and 0.230 standard deviations, respectively. This indicates that the height-for-age z-score was higher for children who had access to safe drinking water, even when the control covariates were significantly higher than that of children who did not have access to safe drinking water. On the contrary, in urban areas, there is no significant difference in the height-for-age z-score between children with access to safe drinking water and children without access to safe drinking water.

Similarly, for the weight-for-height z-score, the propensity score matching results were only significant in rural areas. The results show that in rural areas, access to safe drinking water increased the weight-for-height z-score by 0.275 standard deviations. This indicates that children with access to safe drinking water had significantly higher weight-for-height z-scores than children without access. On the contrary, there was no significant difference in the weight-for-height z-score between children with and without access to safe drinking water in urban areas. However, only the propensity score matching result was statistically significant and the result was not robust for estimation.

Similar results were obtained by Komarul-zaman, Smits, and de Jong (2017) in that access to safe drinking water affected nutrition levels only in rural Indonesia. In their study, the vulnerability of the piped water system in urban areas was interpreted as the cause of such results, although the analysis focused on the effects of piped water on the prevalence of diarrhea.

To assess how large the empirical results were, the present study simulated the changes in nutritional status when children gained access to safe drinking water in rural areas. To consider the heterogeneity of the impact of access to safe drinking water, the treatment effect obtained by matching was added to the nutritional status of each child. Figure 2 shows the results of a simulation of how much the children's nutritional status (height for age z-score and weight for height z-score)

Figure 2. Impact of access to safe drinking water on child nutrition in rural areas



would improve if they could access safe drinking water in rural areas. The dashed line in Figure 2 shows the distribution of children's nutritional status in rural areas, the baseline. The solid line is the distribution of children's nutritional status simulated from the estimation results if children without access to safe drinking water in rural areas can have access.

In the study sample, the number of children in rural areas was 1,073. Among them, 737 children did not have access to safe drinking water. The number of stunted children was 439 and the stunting ratio was about 41 percent. When the treatment effect was added to the height-for-age z-score of children who did not have access to safe drinking water, the number of stunted children decreased to 306 and the stunting ratio dropped to 28 percent. Therefore, access to safe drinking water decreased the stunting ratio by 13 percentage points.

The number of wasted children was 98 and the wasting ratio was 9.1 percent. When the treatment effect was added to the weight-for-height z-score of children who did not have access to safe drinking water, the number of wasted children decreased to 66 and the wasting ratio dropped to 6.1 percent.

Control-Function Approach

Space limitations prevent a detailed discussion of GMM estimation results here. For all estimations, the Wald test accepted the null hypothesis that the correlation of the error terms was zero. This suggests that the conditional mean independence assumption was applicable under the covariates used in the model.

Table 9 reports the estimation results of the ATEs in the control function model. The standard

error was large compared to the ATE estimate and no statistically significant difference from 0 was obtained. Therefore, the estimation of the control function approach was inefficient when the null hypothesis that the correlation of the error terms was 0 was accepted.

Table 10 shows the results of the ATEs estimated under the prior assumption that the correlation of the error term was 0. This estimation is equivalent to estimating equations (6) and (7) individually (i.e., regression adjustment). These results were significant only in rural areas and access to safe drinking water increased the height-for-age z-score by 0.173 standard deviations and the weight-for-height z-score by 0.155 standard deviations. This result is consistent with the matching estimation, although the estimated value is smaller than that of the matching estimation. Therefore, the result is robust to the conditional mean independence assumption.

Table 9. Average treatment effects (control function approach)

Region	Height-for-Age Z-score	Weight-for-Height Z-score
Rural	0.811 (0.911)	-1.170 (1.143)
Sample size	1,073	1,073
Urban	-0.435 (4.418)	-3.298 (4.215)
Sample size	1,222	1,222

Note: The sample size is the number of children.

Table 10. Average treatment effects (regression adjustment)

Region	Height-for-Age Z-score	Weight-for-Height Z-score
Rural	0.173*** (0.098)	0.155*** (0.092)
Sample size	1,073	1,073
Urban	0.072 (0.093)	-0.089 (0.089)
Sample size	1,222	1,222

Note: The sample size is the number of children.

CONCLUSION

Improving the nutritional status of children in urban and rural areas in Indonesia requires more than improving income. This study examined the effects of access to safe drinking water on children's short- and long-term nutritional status by estimating the ATE. No other study on Indonesia has evaluated the causal effects of access to safe drinking water on child nutrition. To mitigate selection bias due to the non-random distribution of access to safe drinking water, a matching estimation was used to quantitatively analyze the effects of access to safe drinking water on child nutrition from IFLS5 data.

The descriptive statistics show that the prevalence of access to safe drinking water in rural areas was about 30 percent, which was considerably lower than the approximate 70 percent in urban areas. Children with access to safe drinking water in rural areas had higher nutritional status than those without access, but there was no significant difference in urban areas.

The results of the ATE obtained from the matching estimation suggest that access to safe

drinking water in rural areas improved both the short- and long-term nutritional status of children, while access to safe drinking water in urban areas had no significant relationship with child nutrition. Based on the simulation results considering that all children in rural areas had access safe drinking water, the stunting ratio and wasting ratios decreased by 13 percentage points and 3 percentage points, respectively.

Furthermore, the analysis using a control function approach that did not assume conditional mean independence accepted the hypothesis that there was no correlation between access to safe drinking water and the unobservable factors affecting children's nutritional status. This suggests that the conditional mean independence assumption holds under the covariates used in the model. The results of the ATE estimation were similar to those of the matching estimation, and the robustness of the effects of safe drinking water on child nutrition in rural areas was maintained.

Certain policy implications may be derived from the estimation results. Considering the low availability of safe drinking water in rural areas, improving access to safe drinking water and increasing the level of household income can improve children's nutritional status. Factors playing a pivotal role in improving access to safe drinking water include household characteristics and community characteristics such as the price of water, presence of a market in the community, and the availability of a bus station (indicating transport accessibility). These variables were related to access to markets. Hence, our results suggest that improving community-related characteristics may improve access to drinking water even for poor households in rural areas, and in turn improve children's nutritional status. Therefore, policymakers should consider ways to improve access to markets for drinking water at the community level. For instance, lowering the price of drinking water is a cost-effective way to increase access to safe drinking water compared to installing piped water in each rural household. This strategy can include subsidizing the production

of bottled water and providing additional cash to low-income rural households to enable them to purchase water.

This study analyzed the direct effects of safe drinking water on the nutritional status of children by assuming that access to safe drinking water affects individual child nutrition only. This assumption is called stable unit treatment values assumption. However, if one child prevents infection by drinking safe water, there is a positive externality that improves the nutritional status of other children in the area. For instance, Usman, Gerber, and von Braun (2019) found that child sanitation practices affected diarrhea incidence in other children. Therefore, there is a positive externality associated with access to safe drinking water. In the IFLS5, some communities did not have a sufficient child sample size; consequently, the mutual impact of children's access to safe drinking water cannot be considered at the community level. This is an important issue because besides individual behavior, the behavior of local residents also affects children's nutritional status. Future research should take this externality into account while investigating the effects of safe drinking water.

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