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The Impact of Access to Improved Sanitation Facilities on Child Health in Pakistan

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Abstract

Poor sanitation is a major public health issue linked to various significant health outcomes. Several studies have associated poor sanitation with malnutrition and childhood diarrhoea. Improved sanitation, however, is determined by household decisions, which may induce endogeneity. Such endogeneity of household sanitation choices has been insufficiently explored in most of the previous literature. Using the Pakistan Demographic and Health Survey (PDHS), we examine the impact of improved sanitation on children's height-for-age, weight-for-age, and weight-for-height z scores, as well as diarrhoea. We address potential endogeneity using an instrumental variable approach. Our findings highlight the significance of better domestic sanitation in improving child health in Pakistan: improved sanitation was found to positively and significantly affect children's growth, mainly height-for-age and weight-for-age in those below five years old. In contrast, no significant impact was identified on weight-for-height and diarrhoea prevalence. The sub-sample analysis showed that particularly girls, children older than two years, children with uneducated mothers, and those from households with poor economic status are positively and significantly affected by access to improved sanitation facilities. Our results were robust throughout different model specifications. We suggest that policies concerning the provision of and enhanced access to improved sanitation are effective in reducing child malnutrition.

Keywords: Child Health, Malnutrition, Diarrhoea, Sanitation Sources, Endogeneity, Pakistan

1. Introduction

Malnutrition is considered a substantial public health concern, especially in developing countries, and it may impact human capital accumulation and impair cognition throughout life (Farid et al., 2013; Galler et al., 2012). Globally, 149.2 million children were found to be stunted (low height-for-age) and over 45.4 million under the age of five were wasted; more than 50% of all wasted children live in Southern Asia (UNICEF, WHO, & World Bank, 2021). Ending hunger and malnutrition is one of the United Nations Sustainable Development Goals (SDGs). Various interrelated factors are considered to be associated with malnutrition, including persistent diarrhoea, insufficient breastfeeding, deficiency of nutritious food, and intestinal infections that weaken a child's nutritional levels (WHO, UNICEF, & World Bank, 2012).

Pakistan is no exception. Malnutrition and child mortality are serious health concerns in the country. Stunting (height-for-age z-score (HAZ) <-2) in the country has worsened and remained at the global critical level of 40.2% in 2018 (National Nutrition Survey, 2018). Therefore, the stunting rate is far higher than the Asia region average of 21.8% (UNICEF, WHO, & World Bank Group, 2021). The prevalence of wasting (low weight-for-height) among children under age five is also rising, with 17.7% of children in Pakistan suffering from this (weight-for-height z-score (WHZ) <-2), the highest rate in the country's history. The prevalence of underweight (weight-for-age z-score (WAZ) < -2) children is 28.9% (National Nutrition Survey Pakistan, 2018). Despite the improvements in various socioeconomic indicators, malnutrition continues to represent a nutrition emergency in the country.

One possible solution to reduce malnutrition and improve child health could be improved sanitation facilities. This is because studies have found human faeces to be a significant reservoir for various pathogenic bacteria and soil-transmitted helminths (STHs), which may cause trachoma, diarrhoea, and environmental enteric disorder (EED) among children (Mara, Lane, Scott, & Trouba, 2010) and lead to malnutrition. The transition from open defecation (OD) to toilet /flush toilet use can contribute by not only offering non-health benefits like saved time (Wang & Shen, 2022) and increased satisfaction but also reducing child mortality and malnutrition (Dickinson, Patil, Pattanayak, Poulos, & Yang, 2015; Geruso & Spears, 2018; Rahman et al., 2020). Studies have revealed that sanitation investments have positive impacts on health outcomes by reducing the exposure to faecal pathogens that occurs due to inappropriate containment of faecal matter (Duflo, Greenstone, Guiteras, & Clasen, 2015; Hammer & Spears, 2013).

Various studies have been conducted to examine the relationship between improved sanitation, child health, and other outcomes, but the results have been inconsistent. Some have observed that improved sanitation can lead to considerable health benefits (Augsburg & Rodríguez-Lesmes, 2018; Bekele, Rahman, & Rawstorne, 2020; Cameron, Olivia, & Shah, 2019; Cameron et al, 2021; Dickinson et al., 2015; Fink, Günther & Hill, 2011; Rahman et al., 2020; Spears, 2020; Spears & Lamba, 2016; Spears, Ghosh, & Cumming, 2013; Vyas, Kov, Smets, & Spears, 2016), educational achievements (Adukia, 2017), and reduced risk of violence towards women (Hossain, Mahajan, & Sekhri, 2022). Freeman et al. (2017) and Headey and Palloni (2019), however, found no significant association between sanitation facilities and child nutritional outcomes.

In addition to these works, several studies have associated poor sanitation with diarrhoea prevalence among children, finding that water, sanitation ans hygiene (WASH) investments are generally considered important for improving early childhood health. Most diarrhoea prevalence is considered to result from contaminated environments. Poor sanitation infrastructure and drinking water contaminated with animal and human faeces contain pathogens, which enter the body through several faecal-oral passageways and cause diarrhoea (Andrés, Briceño, Chase, & Echenique, 2017; Adane, Mengistie, Kloos, Medhin, & Mulat, 2017; Duflo et al. 2015; Fink et al., 2011; Kumar & Vollmer, 2013; Patil et al., 2014; Santika et al., 2020; Usman, Gerber & Braun, 2019; Wasonga, Okowa, & Kioli, 2016). The major limitation of the existing research, however, is that most have failed to consider the endogeneity of household choices regarding sanitation facilities.

The few exceptions include Augsburg and Rodríguez-Lesmes (2018), who empirically examined the impact of sanitation coverage on child height-for-age by using the price of the raw materials needed for toilet construction as an instrumental variable (IV). Geruso and Spears (2018) examined the relationship between neighbourhood sanitation (open defecation) and infant mortality using an IV approach. Other exceptions include the studies based on randomised controlled trials (RCTs), but their results are also mixed. Meanwhile, Dickinson et al. (2015) and Pickering, Djebbari, Lopez, Coulibaly, and Alzua (2015) identified significant impacts of sanitation on children’s height-for-age, weight-for-age, stunting, and underweight, but sanitation was found to have an insignificant impact on diarrhoea. Other RCT-based studies observed that it had no impact on child health, height, or weight (Cameron et al., 2021; Clasen et al., 2014; Patil et al., 2014).

The purpose of this study is to examine the impact of access to improved sanitation facilities on child health, focusing on height-for-age, weight-for-age, weight-for-height, and diarrhoea, by using cross-sectional data from the Demographic Health Survey (DHS) 2017-18 for Pakistan. In examining the impact of improved sanitation, it was recognised that the correlation between the error term and health-related outcomes may be caused by unobservables, including knowledge, beliefs, and attitudes about toilet usage, as well as the mother’s health status. Whereas previous studies have largely failed to consider such facts, we address the endogeneity of household sanitation choices by employing an IV approach. We used the slope of the homestead and the average improved sanitation coverage at the cluster level as the instruments for household sanitation facilities. Height-for-age, weight-for-height, and weight-for-age z-scores[1] among children under five years old were used as child growth indicators. These conventional nutritional indicators are employed as proxies for stunting, underweight, and wasting, respectively (Wang & Chen, 2012).

Having access to improved domestic sanitation facilities was found to result in an average increase in children's height-for-age by 0.43 standard deviations and weight-for-age by 0.32 standard deviations. It had no significant impact, however, on weight-for-height and diarrhoea prevalence. This implies that child health is also damaged by routes other than clinical disorders such as diarrhoea. Recent research implies that environmental enteric dysfunction (EED), a sub-clinical gut condition which spreads rapidly following exposure to faecal-contaminated water and soil, as well as poor sanitation access, has severe impacts on child growth than through diarrhoea, which reduces the absorption of significant nutrients. Whilst inconclusive, our analysis provides suggestive evidence through its mechanism to augment the growing view that improved domestic sanitation impacts child health.

In addition, four sub-sample analyses were undertaken that considered the differential effects of improved sanitation on child health, based on the children's age and gender, the mothers' education, and the household economic status. This approach revealed that sanitation matters little for children below two years old who do not use sanitation facilities, while it significantly affects children older than two years old. The current findings also suggest that girls in particular benefit significantly from improved sanitation in terms of increased weight-for-age and weight-for-height, while such tendencies were not observed for boys. In terms of height-for-age, however, we found few differences between girls and boys regarding the effectiveness of improved sanitation. Moreover, the findings showed that children from poor households are more likely to be positively affected than those from average and above-

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[1] Z-score= Most commonly used reference standard recommended by the WHO for international use. A z-score below -2 reflects stunting, wasting, or underweight; a z-score below -3 reflects severe malnutrition.

average income households. These results imply that vulnerable social groups are more likely to benefit from improved sanitation. These sub-sample analyses add value to this study by providing these insights and highlighting the importance of policy interventions, which were not rigorously examined in previous research.

The remainder of the paper is organised as follows: Section 2 explains the data set and descriptive analyses. Section 3 discusses the econometric estimation strategy. Section 4 presents the estimation results, while Section 5 provides a discussion. Section 6 concludes the study.

2. Data and Variables

2.1. Data

Our study utilised data from the fourth round of the nationally representative Pakistan Demographic Health Survey (PDHS, 2017-18). During the survey, 561 enumeration blocks (hereafter called clusters) were randomly selected, and interviews were conducted with the members of 14,540 households (approximately 28 from each cluster) from urban and rural areas across 143 districts of Pakistan. The data includes information on 12,708 children aged under 60 months, as well as their mothers or caregivers. For the PDHS 2017-18, one-third of the households were selected for anthropometric measurement of the children at the time of the survey. Therefore, our analysis was based on 4,041 children aged 0-59 months whose height and weight were measured. In the PDHS, the enumerators collected geospatial information with a global positioning system (GPS) device to record each cluster's central position. Displacements of 0–5 km in urban areas and 0–2 km in rural areas were added randomly to the GPS information for confidentiality called "geo-scrambled" or "geo-masked".

2.2. Variable Construction

Child growth is measured by three indicators: height-for-age, weight-for-age, and weight-for-height; these measures were operationalised as z-scores scaled to the WHO Child Growth Standards (WHO, 2019; de Onis, Onyango, Borghi, Garza, & Yang, 2006). A child is considered stunted if their height-for-age is less than -2, wasted if their weight-for-height is less than -2, and underweight if their weight-for-age is less than -2. Stunting (low height-for-age) is generally referred to as a sign of long-term chronic undernutrition, a measure of linear growth obstruction and cumulative growth failure that illustrates a history of problematic nutritional and health issues. Wasting (low weight-for-height) is a short-term indicator of acute malnourishment. Underweight (weight-for-age) is a composite index of height-for-age and weight-for-height. We also constructed a binary indicator which took a value of one if a household reported diarrhoea prevalence for a child in the two weeks before the survey.

The main explanatory variable is the improved sanitation binary variable, which took a value of one if the sanitation facility was improved, according to the sanitation technologies classification devised by the WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene (JMP) 2017. Improved sanitation facilities include flushing/pour flushing to piped sewer systems, septic tanks or pit toilets, compositing toilets, ventilated improved pit toilets, and pit toilets with slabs. An unimproved sanitation facility comprises the use of a bush or field, no facility, pit toilets without slabs, open pit toilets, hanging toilets, bucket toilets, compositing or flush toilets to open drains, and un-sewered toilets. Our data shows that about 70% of households in Pakistan use improved sanitation sources, while about 11% still practice OD. The fact that households make their own choices regarding the use of sanitation facilities may have caused bias in our estimation and led to the impact of sanitation on child health being overestimated.

To address the possible endogeneity of sanitation sources, the IV approach and two instruments were used, including the cluster-level average improved sanitation coverage and the homestead slope. We measured the improved sanitation variable at the cluster level by the proportion of households in the cluster, excluding particular households (leave out mean). Cluster-level GPS data was used to measure the slope of each area. If a village had a certain infrastructure such as a sewerage and drainage system, it would be easier for local households to invest in improved sanitation facilities. Thus, we expected to observe a positive correlation between improved sanitation at both household and village level. The homestead slope was expected to be correlated with improved sanitation, since a sanitation system works more effectively when the slope is steeper due to stronger gravity. To protect personal information, the DHS does not include GPS information about the exact locations of homesteads, so the slope gradient variable was calculated based on the cluster-level data provided by the DHS Program. Households could only be located within each cluster.

We used a natural shape file in QGIS containing information about waterways and rivers, along with administrative data about the regions and districts of Pakistan taken from DIVA-GIS. We used slope raster data for Pakistan provided by the Japan Aerospace Exploration Agency (JAXA)[2] . This database is a Global Digital Surface (DSM) model which provides worldwide raster data at resolutions of around 30 metres (basically 1 arc-second). Figure 1 shows the cluster locations obtained from the PDHS and Pakistan administrative data. The slope of each cluster was calculated using the QGIS point sampling tool and based on the elevation rater data and cluster information.

[Figure 1]

In addition, various child, mother, and household characteristics reported in the data were included in the analyses for controlling the observed differences among children. The children’s characteristics include their age, birth size, gender, and delivery place, as well as

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[2] https://www.eorc.jaxa.jp/ALOS/en/dataset/aw3d30/aw3d30_e.htm

whether the child was desired or not at the time of pregnancy. Furthermore, a measure of the children's dietary diversity was constructed using food intake information representative of the children under five years old in the PDHS. Dietary diversity measured how many types of food were consumed by the child in the 24 hours before the survey. A list of the food items consumed by all the children was arranged into eight different categories following WHO guidelines (2017) and the number of food categories they consumed was counted.[3] The mother and household characteristics included the mother's age, education, working status and nutrition status (BMI); the household head's age, gender and education; the interview month, the household size, the number of children under five years old, the time needed by the household to collect water, the water source used by the household, the water treatment status for drinking water,[4] the livestock ownership, cooking fuel, and the household's economic status. The community characteristic included an urban or rural dummy. Appendix Table 1 provides details of the summary statistics of the variables used in the analyses.

3. Methodology

To estimate how the household use of improved sanitation impacted child health, a two-stage least square (2SLS) estimation strategy was used to control for the possible endogeneity caused by the household's selection of sanitation facilities. A correlation

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[3] The eight categories include: 1) Bread, grain, and tubers, 2) Lentils, peas, and nut products, 3) Dairy food (cheese, milk, and yoghurt), 4) Meat products, 5) Eggs, 6) Vitamin-A-rich vegetables and fruit, 7) Green leafy vegetables and other fruits, 8) Breastmilk. Binary variables were created for all the food groups. A value of "0" indicates that the food consumed by the child is different from our list of eight categories. This measure has been validated and accepted for constructing dietary diversity and food adequacy (WHO, 2017; Darapheak, Takano, Kizuki, Nakamura, & Seino et al., 2013; Hirvonen, 2016).

[4] Drinking water sources were categorised into improved and unimproved. The variable takes "1" if the water source is improved (by the nature of its construction or if it is protected from external contamination). For the water treatment status, we created a dummy variable which takes "1" if the household used any water treatment method to treat water for drinking purposes, including boiling, chlorination, filtration, solar disinfection, or straining through a cloth.

between the error term and sanitation facilities could have been caused by unobservables including knowledge, beliefs and attitudes about toilet usage, as well as the mother's health status. This might have affected both the type of sanitation facility and child health.

The following regression equations were estimated. Equation 1 is the first stage of the regression and equation 2 is the second.

$$\mathrm{Sanitation}_{\mathrm{jk}} = \pi_0 + \pi_1 \mathrm{Cluster\_sanitation}_{\mathrm{k}} + \pi_2 \mathrm{Slope}_{\mathrm{k}} + \text{ø}\mathrm{H}_{\mathrm{jk}} + \gamma \mathrm{N}_{\mathrm{k}} + \delta_i + \mathrm{v}_{\mathrm{jk}} \quad (1)$$

$$\mathrm{Y}_{\mathrm{ijk}} = \beta_0 + \beta_1 \mathrm{Sanitation}_{\mathrm{jk}} + \gamma \mathrm{H}_{\mathrm{ijk}} + \theta \mathrm{N}_{\mathrm{k}} + \delta_i + \varepsilon_{\mathrm{ijk}} \quad (2)$$

Where $\mathrm{Y}_{\mathrm{ijk}}$ is the outcome variable indicating the health of child *i* in household *j* in community *k*, including height-for-age, weight-for-age, and weight-for-height as continuous variables and diarrhoea prevalence as a dichotomous variable. $\mathrm{Sanitation}_{\mathrm{jk}}$ is a discontinuous endogenous variable of having improved sanitation at the household level. We included district fixed effects (δ) and used clustered standard errors at the Primary Sampling Unit (PSU) or cluster level. H_{ijk} is a vector for the basic child, mother, and household characteristics, as explained above. N_k is a community characteristic and includes the dummy variable, which takes the value of one if it is a rural location. $\varepsilon_{\mathrm{ijk}}$ is an error term.

As discussed, the instruments used included the average improved sanitation coverage of the cluster and the homestead slope. Village- (or cluster) level improved sanitation coverage would positively affect a local household by enabling access to improved sanitation facilities. This is because when a village has a certain infrastructure, such as a sewerage and drainage system, households find it easier to invest in improved sanitation facilities. In addition, the average improved sanitation coverage cannot be determined by each household, suggesting that the variable can satisfy exclusion restrictions. The slope variable could also be correlated with improved sanitation. If a slope is steeper, the sanitation system works more effectively due to better gravity flow, which may incentivise a household to invest in improved sanitation. Moreover, the homestead slope cannot be changed unless a household moves, which is not easy, at least in the short term. Therefore, these were considered suitable instruments for this study. Reduced-form estimates are presented later in the results section to illustrate the links between these instruments and child health. Various robustness checks were also conducted to examine the validity of the instruments.

4. Results

4.1. Descriptive Analyses

Table 1 compares the outcome variables of children with and without improved household sanitation facilities. The data shows that the average height-for-age, weight-for-age, and weight-for-height are lower for households using unimproved sanitation facilities than for those using such improvements. On average, height-for-age is -2.028 for children from households using unimproved sanitation and -1.364 for those using improved sanitation. The mean height-for-age variable is -1.559 (for the total sample), indicating that, on average, these children were shorter for their age compared to the WHO reference population of the same sex and age. A similar situation was observed for the other malnutrition indicators, i.e., weight-for-age and weight-for-height. On average, the diarrhoeal prevalence was 0.209 among children from households using unimproved sanitation and 0.188 for those whose homes had improved sanitation. The mean comparison test between the households using each type of sanitation also showed statistically significant differences between them for the variables of height-for-age, weight-for-age, weight-for-height and diarrhoea.

[Table 1]

4.2 Main Results

The estimation results concerning the impact of improved sanitation on child height-for-age, weight-for-age, and weight-for-height, as well as diarrhoea prevalence, are presented in Table 2. The first-stage estimates are shown in Panel A. The cluster-level average improved sanitation and homestead slope values have strong positive correlations with improved sanitation. The first-stage *F*-statistics for the set of excluded instruments remained over 10, suggesting that weak instruments did not bias our estimates. Furthermore, an over-identification test of the instruments was conducted, which mainly led to the null hypothesis not being rejected, suggesting that at least one of the instruments is exogenous.

To explain the correlation between these instruments and the height-for-age, weight-for-age, weight-for-height, and diarrhoea prevalence outcome variables, the reduced-form estimates are presented in Appendix Table 2. The results show that a correlation exists between our instruments and child health, which may have arisen through household improved sanitation. Appendix Figure 1 presents the Frisch Waugh Lovell (FWL) theorem results, where the residuals of the first-stage estimation are plotted on the horizontal axes, while the residuals of reduced-form estimation and the outcome variables are plotted on the vertical axes. The results suggest that these instruments are valid and that our model is logically defined.

In Panels B and C of Table 2, the authors use OLS and 2SLS to report the estimated coefficient of interest β_1 on the impact of improved sanitation facilities on the children's height-for-age, weight-for-age, weight-for-height, and diarrhoea prevalence. The OLS results, shown in Panel B, demonstrate the positive and statistically significant relationships between improved sanitation and both height-for-age and weight-for-age. Conversely, the coefficients of improved sanitation on weight-for-height and diarrhoea are statistically insignificant.

Panel C reports the 2SLS estimation results. While accounting for endogeneity by instrumenting with the cluster-level improved sanitation coverage and homestead slope, the coefficients for the children's height-for-age and weight-for-age were found to be significant, at 10%. The estimated coefficients from the IV regressions, shown in columns 1 and 2, suggest that having improved sanitation facilities resulted in the children's height-for-age being higher by 0.43 standard deviations and their weight-for-age being higher by 0.32 standard deviations. In contrast, columns 3 and 4 indicate the insignificant effects of improved sanitation on a child's weight-for-height and diarrhoea. Generally, the 2SLS estimates are consistent with the OLS estimates, suggesting the robustness of our results (see Appendix Table 3 for full results).

[Table 2]

4.3 Heterogeneous Impacts of Improved Sanitation

Within the empirical analyses, the authors examined whether the effects of sanitation were heterogeneous across different child age groups and households of different socioeconomic status. More specifically, the impact of improved sanitation on child health was compared by the children's age and gender, the mothers' education, and the economic status of the household.

First, we focus on the age of the children. Heterogeneity may exist based on their age because sanitation sources do not affect all children in the same manner. Table 3 presents the results of the sub-sample analyses based on each child's age. The estimated significant coefficients of 0.60 and 0.46 (in columns 5 and 6, respectively) from the 2SLS regressions for children older than two years suggest that having improved sanitation facilities resulted in significantly higher children's height-for-age and weight-for-age. In contrast, columns 1 and 2 indicate the insignificant effects of improved sanitation on children's height-for-age and weight-for-age for those younger than two years of age. Similar to our main results, the effects of improved sanitation on weight-for-height and diarrhoea were found to be insignificant for both child age groups.

[Table 3]

Secondly, we focus on the gender of the children. Since families in Pakistan generally prefer boys to girls, improved sanitation facilities may have different impacts on boys and girls. The results of the gender-based sub-sample analysis are presented in Table 4. In Panel A, the OLS and 2SLS estimates are reported for female children. Columns 1 and 2 for the OLS estimates show the positive and significant impacts of access to improved sanitation facilities on girls' height-for-age and weight-for-age. The 2SLS estimates (shown in columns 2 and 3) indicate the positive and significant impacts on girls' weight-for-age and weight-for-height. In Panel B, the OLS estimates for height-for-age are significant at 5% for male children. The coefficient became insignificant, however, for the 2SLS estimates. Columns 3 and 4 show the insignificant effects of improved sanitation on weight-for-height and diarrhoea prevalence for boys, which is consistent with our full sample analysis.

[Table 4]

What potential reasons could explain the different impacts of improved sanitation on male and female child health? The major share of the gender inequalities in South Asia can be attributed to nutritional imbalances. Boys are believed to receive more vitamin supplements and childcare time, and they are more likely to be breastfed and vaccinated (Augsburg & Rodríguez-Lesmes, 2018). Previous studies also show that boys are more likely to receive immunisation and better access to medical professionals (Hazarika, 2000). In our data set, boys and girls were also compared regarding access to healthcare facilities and nutrition (Appendix Table 4). The results indicate that boys are more likely than girls to be immunised, have better vaccination status, receive better medical services in cases of diarrhoea and fever, and be given diverse types of dairy food. Furthermore, as shown in Appendix Table 5, OLS regression was run to examine the association between the child's gender and parental investment behaviour regarding child healthcare and nutrition. The estimated results highlight how girls are less likely than boys to receive diverse types of food (particularly dairy), medical treatment, or any treatment given for diarrhoea and fever.

Table 5 displays the heterogeneous effects based on the wealth status of the households. The wealth quantiles reported in the PDHS were categorised into below-average (the poorest and poor) and average or above-average (the middle, richer, and richest) households. Panel A shows the results of the OLS and 2SLS estimates for the poor households. These results illustrate that, generally, the height-for-age and weight-for-age of children from households of below-average economic status were significantly affected by improved sanitation facilities. Meanwhile, column 3 shows that our results remained insignificant in regard to weight-for-height. Column 4 in Panel A shows the estimated coefficient of improved sanitation on diarrhoea for children. Improved sanitation was observed to be positively associated with the diarrhoea prevalence of children from poor households, for which no satisfactory explanations can be given. Panel B presents the results of the households of average and above-average (rich) economic status. We found the effects of improved sanitation on non-poor households to be insignificant. Overall, the results are consistent with our main analyses in showing that improved sanitation positively affects height-for-age and weight-for-age and these effects can mainly be identified in poor households.

[Table 5]

The authors also tested whether the mother's education level influenced the impact of sanitation facilities on child health. The mother's education was defined as a dummy variable which took a value of one if the mother had completed education at primary level or above. Educated mothers could be expected to have the capacity to protect their children from disease environments and health issues by having better awareness and knowledge of handwashing and sanitation-related hygiene practices (Olubukola, 2014). Columns 1 and 2 of Table 6 show the estimated coefficients of 1.20 and 0.48 from the 2SLS regressions, suggesting that having improved sanitation facilities resulted in significantly higher height-for-age and weight-for-age for households where the children had uneducated mothers. In contrast, columns 5 and 6 indicate the insignificant effects of improved sanitation on the height-for-age and weight-for-age of children of educated mothers. Similar to our main results, neither educated nor uneducated mothers appeared to significantly affect weight-for-height or diarrhoea.

[Table 6]

4.4 Robustness Checks and Sensitivity Analysis

Several checks were conducted to examine the robustness of the main results. First, the authors examined the sensitivity of the coefficients to the control variables selected. The main results included as controls were the characteristics of the child, the household head, the mother, and the household. For the robustness check, certain control variables were excluded. The results, shown in Appendix Table 6, demonstrate that the size of the coefficients and the statistical significance were stable across different estimations, suggesting the robustness of our results.

The second robustness check was related to the omitted-variable bias and the exclusion restriction of the IVs. One of the potentially most important omitted variables in our estimation was the drinking water quality, since this may directly affect child health. Nevertheless, poor sanitation facilities may affect the quality of the drinking water because of the discharge of microbial and chemical contaminants from pit toilets into groundwater, as well as the dumping of faecal sludge into rivers and other open places, can contribute to water pollution. Therefore, if access to clean water had been included in the error term, this might have caused omitted-variable bias in the estimates. To determine the extent to which our IV estimates were sensitive to these controls, both regressions were run with and without the household drinking water source and water treatment-related covariates. The coefficients reported in columns 5-8 in Appendix Table 7 show that the results with and without the access to drinking water related control variables are almost identical in terms of the significance and size of the coefficients, suggesting the robustness of our results.

Thirdly, the authors examined the mechanism through which improved sanitation affects child health. It was assumed that improved sanitation would positively impact child health through reductions in bowel infections and gut disorders. However, improved sanitation was found to affect child health possibly in other ways. To examine such possibilities, coughing, the common cold, fever, and breathing issues were constructed as dummy variables, based on the PDHS. Appendix Table 8 illustrates the impact of improved sanitation on these other child health issues. The results in columns 1-4 show that improved sanitation has insignificant effects on these health issues, which could mediate child growth.

5. Discussion

The authors examined the impact of access to improved sanitation facilities on child health by addressing the endogeneity of household access to sanitation. The results suggest that children are less likely to suffer from malnutrition issues if they have access to improved sanitation facilities, which was mainly reflected in the height-for-age and weight-for-age. In contrast, improved sanitation was found to have insignificant effects on weight-for-height and diarrhoea prevalence. The results were confirmed as robust in different model specifications.

One unexplained aspect of our results is that improved sanitation affects child health without diarrhoea prevalence. A possible explanation for this is that increased household access to improved sanitation might reduce the prevalence of intestinal worm infections, which can cause malnutrition among children. An alternative explanation is that less environmental faecal contamination might contribute to lower environmental enteropathy among children (a sub-clinical disorder), resulting in better nutrient absorption in the gut and improved child growth. In fact, Humphrey (2009) and Mbuya and Humphrey (2016) found that environmental enteric dysfunction (EED) may hamper a child's growth more severely than diarrhoea. One limitation, however, is that the diarrhoea variable captured diarrhoea incidence only in the two weeks preceding the survey. Moreover, diarrhoeal illness was measured for this survey mainly during the dry season, and improved sanitation may have been found to affect diarrhoea risk differently if the rainy season had been included or if long-term diarrhoea prevalence had been measured. Therefore, the mechanism through which improved sanitation facilities enhance child growth remained uncertain.

Overall, our results corroborate the findings in the existing literature. In terms of magnitude, the estimated impacts identified in this study are comparable to the findings of Dickinson et al. (2015) in India, where improved sanitation was found to increase height-for-age by 0.37–0.52 standard deviations and weight-for-age by 0.26–0.31 standard deviations, while diarrhoeal illness was not reduced significantly. Hammer and Spears (2013) found that an increase in toilet ownership of 8.2 percentage points increased height-for-age by 0.3–0.4 standard deviations for children aged four years old in Madhya Pradesh, India. Moreover, the findings of Pickering et al. (2015) also suggest that improved access to sanitation does not significantly prevent child diarrhoea. The results of our study are consistent with those of previous researchers, in that a poor household sanitation environment was found to pose a risk to child growth failure, but it had no statistically significant impact on diarrhoea prevalence.

While examining the heterogeneous effects of improved sanitation with regard to gender, different child age groups, and varying household socioeconomic status, it was found that children older than two years benefitted more from improved sanitation. This may have been because children under two do not use the toilet and are less likely to move around outside their dwelling. In addition, children are usually breastfed at this younger age, so they benefit from the antibodies in breastmilk.

Our findings for the gender-based heterogeneous effects reveal that the positive impacts of improved sanitation on weight-for-age and weight-for-height were mainly driven by the effects on girls. Potential reasons were sought for the heterogeneous impacts of improved sanitation on male children compared to females, and the results indicate that girls are less likely than boys to receive diverse types of food (particularly dairy food), medical treatment, or any treatment for diarrhoea or fever. Such preferential nutrition and health investments in boys might explain why improved sanitation matters more for girls. Since male children receive better healthcare and nutrition treatment, their growth may not be substantially hindered, even if the household is not equipped with improved sanitation facilities.

The heterogeneous effects in regard to rich and poor households imply that improved sanitation has insignificant effects on non-poor households. One reason could be that over 90% of the above-average economic status households were already using improved sanitation and their sanitation use did not vary. Therefore, improved sanitation facilities were found to have no strong impact on child health among rich households. On the other hand, improved sanitation was found to positively affect the height-for-age and weight-for-age for children from poor households, which is consistent with our main results.

Similarly, we found a significant and positive impact of improved sanitation on child health for those with uneducated mothers, while no such effects were found for children of educated mothers. This might have been due to the minimal variation among households containing educated mothers, with more than 88% of such households already using improved sanitation. When sanitation improves, the children of uneducated mothers appear to benefit more than those with educated mothers.

6. Conclusion

This study analysed the impacts of household sanitation facilities on children’s height-for-age, weight-for-age, weight-for-height, and diarrhoea in Pakistan using the IV approach. The key finding is that access to improved sanitation significantly affects a child’s height-for-age and weight-for-age , although it does not significantly affect diarrhoeal prevalence and weight-for-height among children. These findings were obtained after controlling for endogeneity problems such as unobserved mothers' behaviour towards child health or sanitation as a whole.

This study also revealed differential impacts of improved sanitation facilities on child health, depending on the child's age and sex, the mother's education, and the economic status of the household. Firstly, children above two years of age seem to benefit more from improved sanitation than younger children because the latter do not use the toilet. Secondly, girls benefit more from improved sanitation than boys, probably because the former are likely to be discriminated against in terms of child healthcare and nutrition. Thirdly, households where the children have uneducated mothers are more affected by improved sanitation than those with educated mothers. The authors also found that children from poor households are likely to benefit more from improved sanitation than those from rich households, possibly because the latter were generally already using improved sanitation and their sanitation use varied minimally. If sanitation were improved through policies or projects, children living in unfavourable conditions may gain greater benefits.

Certain policy recommendations can be highlighted following this study. Firstly, improved sanitation facilities may significantly reduce the risk of child malnutrition, which could positively influence their overall development and economic opportunities later in life. Moreover, the potential benefits from access to improved sanitation facilities may influence non-health-related outcomes, primarily household time use. Secondly, compared to their opposites/counterparts, girls, children of poor households, and those with uneducated mothers are more likely to be affected by improved sanitation. Considering the government's financial limitations, public funding allocations should be diverted towards such groups to reduce the disparity in growth between children living in favourable conditions and those living in unfavourable conditions in the country.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

The data used in this study for analysis came from the DHS Program (https://dhsprogram.com/Data/) and is publicly archived and available to download on request.

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Table 1. Mean comparison tests for the child health with and without improved sanitation facilities in the household

	Sanitation sources			
Variables	Unimproved	Improved	Total	t-test
Height-for-age	-2.028	-1.364	-1.559	0.66***
Weight-for-age	-1.470	-0.919	-1.081	0.55***
Weight-for-height	-0.402	-0.173	-0.240	0.23***
Diarrhoea	0.209	0.188	0.194	0.02*
No. of Observations	1,190	2,851	4,041	

Source: Authors' calculations. *** indicates significant at 1%, ** significant at 5% and * significant at 10% in mean comparison test between households using unimproved and improved sanitation facilities.

Table 2. Effects of improved sanitation on child health - OLS & 2SLS

	Dependent Variable: Sanitation facilities (1=improved)			
Variables	(1)	(2)	(3)	(4)
Panel A. First-stage estimates				
Cluster mean improved sanitation (except self)	0.832***	0.438***	0.436***	0.441***
	(0.0148)	(0.0357)	(0.0358)	(0.037)
Slope (degree)	0.00051**	0.0019**	0.0019**	0.0020**
	(0.0002)	(0.0008)	(0.0008)	(0.0008)
Controls				
District Fixed Effect	No	Yes	Yes	Yes
Child characteristics	No	No	Yes	Yes
Household characteristics	No	No	No	Yes
R-squared	0.351	0.438	0.447	0.452
Kleibergen-Paap F-statistic	86.13	86.13	86.13	86.13
	Height-for-age	Weight-for-age	Weight-for-height	Diarrhoea
Variables	(1)	(2)	(3)	(4)
Panel B. OLS estimates				
Sanitation source (1=Improved, otherwise 0)	0.211***	0.105**	-0.016	-0.004
	(0.07)	(0.05)	(0.05)	(0.01)
R-squared	0.247	0.275	0.188	0.097
Panel C. 2SLS estimates				
Sanitation source (1=Improved, otherwise 0)	0.437*	0.329*	0.101	0.033
	(0.25)	(0.18)	(0.19)	(0.06)
R-squared	0.115	0.119	0.046	0.052
Controls (all)	Yes	Yes	Yes	Yes
Basmann over-identification (*p*-value)	0.537	0.906	0.585	0.090
Observations	4,041	4,041	4,041	4,041
No. of households	2,464	2,464	2,464	2,464

Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1 *Source*: Authors' calculations.

Table 3. Differential effects of sanitation on child health by age group

	Younger than 2 years of age (2SLS)				Older than 2 years of age (2SLS)			
	Height-for-Age	Weight-for-Age	Weight-for-Height	Diarrhea	Height-for-Age	Weight-for-Age	Weight-for-Height	Diarrhea
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sanitation source (1=Improved, otherwise 0)	0.259	0.172	-0.011	0.01	0.601*	0.469**	0.171	0.043
	-0.341	-0.263	-0.284	-0.113	-0.334	-0.229	-0.23	-0.073
R-squared	0.126	0.096	0.036	0.02	0.073	0.114	0.052	0.042
Observations	1,662	1,662	1,662	1,662	2,379	2,379	2,379	2,379
Over-identification test(p-value)	0.828	0.971	0.986	0.684	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-Statistics	64.35				54.7			

Source: Authors' calculations. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4. Differential effects of sanitation on child health by gender

Variables	Height-for-age (1)	Weight-for-age (2)	Weight-for-height (3)	Diarrhoea (4)
Panel A.				
Female Children (OLS)				
Sanitation source (1=Improved, otherwise 0)	0.166*	0.140**	0.061	0.009
	(0.092)	(0.065)	(0.077)	(0.026)
R-squared	0.286	0.317	0.230	0.144
Female Children (2SLS)				
Sanitation source (1=Improved)	0.454	0.719***	0.589**	0.043
	(0.330)	(0.253)	(0.259)	(0.089)
R-squared	0.16	0.10	0.03	0.07
Observations	1,997	1,997	1,997	1,997
F-statistic	43.78	43.78	43.78	43.78
Basmann over-identification (*p*-value)	0.021	0.381	0.665	0.053
Panel B.				
Male Children (OLS)				
Sanitation source (1=Improved)	0.273**	0.089	-0.072	-0.015
	(0.107)	(0.080)	(0.083)	(0.027)
R-squared	0.2730	0.3023	0.2371	0.1299
Male Children (2SLS)				
Sanitation source (1=Improved, otherwise 0)	0.404	-0.059	-0.368	0.034
	(0.334)	(0.232)	(0.266)	(0.095)
R-squared	0.12	0.13	0.04	0.03
Observations	2,044	2,044	2,044	2,044
F-statistic	52.17	52.17	52.17	52.17
Basmann over-identification (*p*-value)	0.024	0.442	0.242	0.560
Controls	Yes	Yes	Yes	Yes

Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculations. 2SLS results report correlations between sanitation and gender-based child health variables.

Table 5. Differential effects of sanitation on child health by household's wealth status

Variables	Height-for-age (1)	Weight-for-age (2)	Weight-for-height (3)	Diarrhoea (4)
Panel A.				
Below-average households (OLS)				
Sanitation source (1=Improved, otherwise 0)	0.228**	0.139*	0.026	-0.012
	(0.102)	(0.070)	(0.083)	(0.026)
R-squared	0.26	0.28	0.25	0.14
Below-average households (2SLS)				
Sanitation source (1=Improved)	0.771*	0.539*	0.278	0.179**
	(0.418)	(0.280)	(0.331)	(0.080)
R-squared	0.10	0.06	0.02	0.01
Observations	1,860	1,860	1,860	1,860
F-statistic	21.65	21.65	21.65	21.65
Basmann over-identification (*p*-value)	0.584	0.267	0.407	0.017
Panel B.				
Above-average households (OLS)				
Sanitation source (1=Improved)	0.122	-0.001	-0.121	-0.009
	(0.100)	(0.080)	(0.092)	(0.033)
R-squared	0.22	0.25	0.18	0.12
Above-average households (2SLS)				
Sanitation source (1=Improved, otherwise 0)	-0.027	-0.000	-0.112	-0.106
	(0.518)	(0.350)	(0.374)	(0.157)
R-squared	0.09	0.13	0.04	0.04
Observations	2,181	2,181	2,181	2,181
F-statistic	25.96	25.96	25.96	25.96
Basmann over-identification (*p*-value)	0.263	0.711	0.228	0.816
Controls	Yes	Yes	Yes	Yes

Source: Authors' calculations. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6. Differential effects of sanitation on child health by woman literacy

	Mother uneducated				Mother educated			
	Height-for-age	Weight-for-age	Weight-for-height	Diarrhoea	Height-for-age	Weight-for-age	Weight-for-height	Diarrhoea
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sanitation source (1=Improved)	1.200***	0.476*	-0.242	-0.001	-0.280	0.205	0.426	0.080
	(0.419)	(0.282)	(0.282)	(0.074)	(0.395)	(0.269)	(0.302)	(0.117)
R-squared	0.058	0.077	0.037	0.047	0.108	0.122	0.044	0.054
Observations	2,060	2,060	2,060	2,060	1,981	1,981	1,981	1,981
Over-identification test (p-value)	0.691	0.344	0.490	0.091	0.905	0.258	0.344	0.666
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-Statistics	27.43				33.30			

Source: Authors’ calculations. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Appendix

Table 1. Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Explanatory Variables					
Sanitation source (1=improved, 0=otherwise)	4,041	0.66	0.48	0	1
Height-for-age z-score	4,041	-1.56	1.67	-5.99	5.81
Weight-for-age z-score	4,041	-1.08	1.25	-5.90	3.90
Weight-for-height z-score	4,041	-0.24	1.28	-4.94	4.99
Diarrhoea (1=yes)	4,041	0.19	0.39	0	1
Children					
Age in years	4,041	2.01	1.41	0	4
Age in months	4,041	29.32	17.35	0	59
Female (1=yes)	4,041	0.49	0.50	0	1
Birth size (1=small, 2=average, 3= large)	4,041	1.90	0.48	1	3
Dietary diversity (0=no group…,6=six groups)	4,041	0.99	0.86	0	6
Child wanted at pregnancy (1=yes)	4,041	0.82	0.37	0	1
Delivery at government hospital (1=yes)	4,041	0.27	0.44	0	1
Delivery at private hospital (1=yes)	4,041	0.37	0.48	0	1
Delivery at home (1=yes)	4,041	0.31	0.46	0	1
HH Head's & Mother's Characteristics					
Age of HH head (years)	4,041	46.56	15.18	16	95
HH head education (1=yes)	4,041	0.002	0.04	0	1
HH head gender (1=male)	4,041	0.89	0.30	0	1
Age of mother (years)	4,041	29.11	6.08	15	49
Mother's education (1=yes)	4,041	0.49	0.49	0	1
Mother's working status (1=yes)	4,041	0.11	0.31	0	1
Mother's BMI (mean)	4,041	25.01	5.30	12.93	52.48
HH Characteristics					
Number of children under 5 (number)	4,041	2.46	1.51	0	11
Month of Interview (mean)	4,041	4.56	4.56	1	12
Wealth quantile index (1=poorest,…, 5=richest)	4,041	2.84	1.38	1	5
Water source (1=improved, 0=otherwise)	4,041	0.91	0.28	0	1
HH uses treated water (1= yes)	4,041	0.10	0.29	0	1
Distance to water source (minutes)	4,041	1.39	0.69	1	3
Cooking fuel clean (1= yes)	4,041	0.42	0.49	0	1
HH owns livestock (1= yes, 0=otherwise)	4,041	0.50	0.50	0	1
HH size (no. of rooms)	4,041	2.43	1.41	0	12
Community Variables					
Cluster mean improved sanitation (except self)	4,041	25.40	90.24	0	480
Area of residence (1=rural, 0=urban)	4,041	0.54	0.49	0	1
Slope (degree)	4,041	3.21	4.93	0	23
Total Households	2,464				

Source: Authors' calculations. Pakistan Demographic and Health Survey (PDHS), 2017-18.

Table 2. Reduced-form estimates (N=4,041)

	Dependent Variable			
	Height-for-age	Weight-for-age	Weight-for-height	Diarrhoea
Variables	(1)	(2)	(3)	(4)
Cluster mean improved sanitation	0.178	0.147*	0.0549	0.0252
	(0.114)	(0.0833)	(0.0911)	(0.0307)
Slope (degree)	0.00339	0.000333	-0.00154	-0.00170*
	(0.00384)	(0.00283)	(0.00346)	(0.000871)
Controls				
District Fixed Effect	Yes	Yes	Yes	Yes
Child and Household characteristics	Yes	Yes	Yes	Yes
Observations	4,041	4,041	4,041	4,041
R-squared	0.246	0.275	0.189	0.098

Source: Authors' calculations. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 3. 2SLS estimates of the impact of sanitation on child health: Full Sample (N=4,041)

Variables	Height-for-age	Weight-for-age	Weight-for-height	Diarrhoea
	(1)	(2)	(3)	(4)
Improved sanitation (1=yes)	0.4373*	0.3290*	0.1012	0.0336
	(0.2561)	(0.1846)	(0.1901)	(0.0660)
Age in months (0-59)	-0.0254***	-0.0121***	0.0033**	-0.0034***
	(0.0016)	(0.0011)	(0.0013)	(0.0004)
Birth size (average)	0.3301***	0.4065***	0.2608***	-0.0802***
	(0.0693)	(0.0512)	(0.0536)	(0.0183)
Birth size (large)	0.5804***	0.7534***	0.5419***	-0.0280
	(0.0977)	(0.0732)	(0.0798)	(0.0283)
Female child (1=yes)	0.0450	0.0103	0.0229	-0.0087
	(0.0449)	(0.0341)	(0.0383)	(0.0120)
Dietary diversity (1 food group)	0.0342	0.0554	-0.0002	0.0322**
	(0.0569)	(0.0444)	(0.0473)	(0.0146)
Dietary diversity (2 food groups)	-0.0196	0.0328	-0.0284	0.0285
	(0.0766)	(0.0559)	(0.0589)	(0.0189)
Dietary diversity (3 food groups)	0.0835	0.0873	-0.0674	0.0938**
	(0.1514)	(0.0998)	(0.0989)	(0.0421)
Dietary diversity (4 food groups)	0.2891	0.2999*	0.0497	0.0339
	(0.2518)	(0.1642)	(0.1413)	(0.0694)
Dietary diversity (5 food groups)	0.2575	0.5341***	0.3863	-0.2102***
	(0.3398)	(0.1771)	(0.3116)	(0.0282)
Dietary diversity (6 food groups)	1.2603***	1.2872***	0.5899	-0.2676***
	(0.2309)	(0.3547)	(0.4608)	(0.0804)
Children under age 5 (No.)	-0.0018	-0.0069	-0.0142	-0.0089*
	(0.0211)	(0.0170)	(0.0180)	(0.0053)
Child wanted at pregnancy time (1=yes)	0.0377	0.0097	-0.0094	-0.0428**
	(0.0687)	(0.0507)	(0.0503)	(0.0191)
Delivery in government hospital (1=yes)	0.0260	-0.0265	-0.0576	0.0133
	(0.1276)	(0.1112)	(0.1030)	(0.0366)
Delivery in private hospital (1=yes)	0.1709	0.0935	0.0121	0.0130
	(0.1228)	(0.1072)	(0.1012)	(0.0357)
Delivery at home (1=yes)	-0.0251	-0.1359	-0.1599	0.0171
	(0.1252)	(0.1084)	(0.1002)	(0.0344)
Interview month	-0.0138	-0.0034	0.0071	0.0008
	(0.0087)	(0.0071)	(0.0067)	(0.0029)
Age of HH head (years)	-0.0039*	-0.0024	0.0001	-0.0007
	(0.0020)	(0.0016)	(0.0017)	(0.0005)
HH head gender (1=male)	-0.0326	-0.0485	-0.0509	-0.0208
	(0.0860)	(0.0641)	(0.0758)	(0.0242)
HH head education (1=yes)	0.9454**	0.5984*	0.0510	0.0066
	(0.4285)	(0.3356)	(0.3566)	(0.0424)
Age of mother (years)	0.0156***	0.0049	-0.0062*	-0.0015
	(0.0048)	(0.0034)	(0.0037)	(0.0011)
Mother’s education (1=yes)	0.2936***	0.1628***	-0.0248	0.0452***
	(0.0709)	(0.0536)	(0.0534)	(0.0167)
Mother’s working status (1=yes)	-0.0311	0.0201	0.0792	-0.0145
	(0.0856)	(0.0636)	(0.0594)	(0.0179)
Mother’s BMI (mean)	0.0198***	0.0261***	0.0214***	-0.0008
	(0.0053)	(0.0042)	(0.0043)	(0.0013)
Household size (no. of rooms)	-0.0321	-0.0274	-0.0157	-0.0008
	(0.0267)	(0.0189)	(0.0253)	(0.0064)
Cooking fuel clean (1= yes)	-0.0639	-0.1110*	-0.1183*	0.0276
	(0.0878)	(0.0664)	(0.0654)	(0.0219)
Water source (1= improved)	-0.1403	-0.0428	0.0702	-0.0081
	(0.1098)	(0.0834)	(0.0961)	(0.0277)

HH uses treated water (1= yes)	0.1535*	0.0771	0.0024	0.0024
	(0.0891)	(0.0667)	(0.0631)	(0.0228)
Distance to water source (minutes)	-0.0174	0.0016	0.0238	-0.0074
	(0.0565)	(0.0350)	(0.0340)	(0.0111)
HH owns livestock (1= yes, 0=otherwise)	0.0518	0.0658	0.0311	-0.0053
	(0.0642)	(0.0477)	(0.0499)	(0.0165)
Household area of residence (1=rural, 0=urban)	0.0383	0.0312	0.0115	0.0067
	(0.0680)	(0.0502)	(0.0524)	(0.0204)
Wealth index (poorer)	0.1823	0.1008	-0.0161	-0.0294
	(0.1255)	(0.0873)	(0.0876)	(0.0313)
Wealth index (middle)	0.1584	0.2075*	0.1458	-0.0407
	(0.1577)	(0.1134)	(0.1102)	(0.0375)
Wealth index (richer)	0.3173*	0.3072**	0.1926	-0.0567
	(0.1895)	(0.1360)	(0.1380)	(0.0447)
Wealth index (richest)	0.5135**	0.5538***	0.3962**	-0.1115**
	(0.2145)	(0.1550)	(0.1605)	(0.0533)

Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4. Mean comparison of healthcare and nutrition status by gender

	Observations	Male	Female	t-test
Immunisation status of child (1=yes)	4,041	0.175	0.157	0.017*
Pneumococcal Vaccine (1=yes)	4,041	0.278	0.252	0.025*
Postnatal checkup (1=yes)	2,671	0.442	0.424	0.018
Wealth status of household	4,041	2.892	2.806	0.085**
Dietary diversity (1,…..8)	4,041	1.014	0.976	0.038*
Breastfeeding ever (1=yes)	2,595	0.345	0.315	0.030**
Fruit & Vegetables	4,041	0.381	0.362	0.019*
Dairy products	2,546	0.043	0.027	0.015**
Medical treatment for fever	1,646	0.737	0.687	0.050**
Visited private hospital for fever	1,646	0.378	0.352	0.026
Any treatment for fever	1,646	0.801	0.741	0.060***
Visited private hospital for diarrhoea	787	0.287	0.263	0.023
Medical treatment for diarrhoea	787	0.618	0.553	0.065**
Any treatment for diarrhoea	787	0.702	0.605	0.097***

Source: Authors’ calculations.

Table 5. OLS results on the association between gender and healthcare and nutrition status

	Food Diversity	Dairy Food	Meat, fruit & vegetables	Bread, noodles & grain	Breastfeeding	Pneumococcal vaccine	Immunisation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Female Child (1=yes)	-0.017	-0.015**	-0.016	-0.001	-0.024	-0.007	-0.011
	(0.025)	(0.006)	(0.011)	(0.016)	(0.017)	(0.010)	(0.009)
Controls							
District Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household & Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,041	2,546	4,041	2,546	2,595	4,041	4,041
R-squared	0.20	0.12	0.45	0.22	0.30	0.60	0.31

	Medical Treatment Diarrhoea	Private Hospital Diarrhoea	Any Treatment Diarrhoea	Medical Treatment Fever	Private Hospital Fever	Any Treatment Fever	Postnatal care
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Female Child (1=yes)	-0.077*	-0.041	-0.101**	-0.050**	-0.032	-0.060***	-0.025
	(0.041)	(0.037)	(0.042)	(0.022)	(0.024)	(0.022)	(0.016)
Controls							
District Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household & Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	787	787	787	1,646	1,646	1,646	2,671
R-squared	0.24	0.26	0.23	0.21	0.21	0.18	0.17

Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6. 2LSL Regression results for the robustness check on the impact of improved sanitation on child health (N=4,041)

Variables	Height-for-age			Weight-for-age		
	(1)	(2)	(3)	(4)	(5)	(6)
Sanitation source (1=Improved)	0.914***	0.511***	0.437*	0.785***	0.416***	0.329*
	(0.17)	(0.18)	(0.25)	(0.12)	(0.13)	(0.18)
Controls						
Child characteristics	No	Yes	Yes	No	Yes	Yes
Household head's and Mother's characteristics	No	Yes	Yes	No	Yes	Yes
Household characteristics	No	No	Yes	No	No	Yes
F-Statistics	251	176	86	251	176	86

Variables	Weight-for-height			Diarrhoea		
	(7)	(8)	(9)	(10)	(11)	(12)
Sanitation source (1=Improved)	0.352***	0.177	0.101	0.026	0.007	0.033
	(0.12)	(0.14)	(0.19)	(0.04)	(0.04)	(0.06)
Controls						
Child characteristics	No	Yes	Yes	No	Yes	Yes
Household head's and Mother's characteristics	No	Yes	Yes	No	Yes	Yes
Household characteristics	No	No	Yes	No	No	Yes
F-Statistics	251	176	86	251	176	86

Source: Authors. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7. 2SLS estimates on the impact of sanitation on child health with and without controlling drinking water quality variables

	2SLS (with drinking water quality variables)				2SLS (without drinking water quality variables)			
	HAZ	WAZ	WHZ	Diarrhoea	HAZ	WAZ	WHZ	Diarrhoea
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sanitation source (1=Improved)	0.437*	0.329*	0.101	0.033	0.441*	0.330*	0.098	0.034
	(0.25)	(0.18)	(0.19)	(0.06)	(0.256)	(0.185)	(0.190)	(0.066)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Over-identification test	0.537	0.906	0.585	0.090	0.437	0.974	0.546	0.096
F-Statistics	86.13				85.60			
Observations	4,041	4,041	4,041	4,041	4,041	4,041	4,041	4,041

Source: Authors. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 8. 2SLS estimates of the impact of sanitation on alternative child health issues (N=4,041)

Variables	Dependent Variable: Other Health Issues			
	Cough	Common cold	Fever	Breathing issues
	(1)	(2)	(3)	(4)
Sanitation source (1=Improved)	0.121	0.066	0.028	0.058
	(0.092)	(0.072)	(0.084)	(0.073)
Controls	Yes	Yes	Yes	Yes
Over-identification test (*p*-value)	0.630	0.421	0.890	0.931

Source: Authors. Clustered standard errors at PSU level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

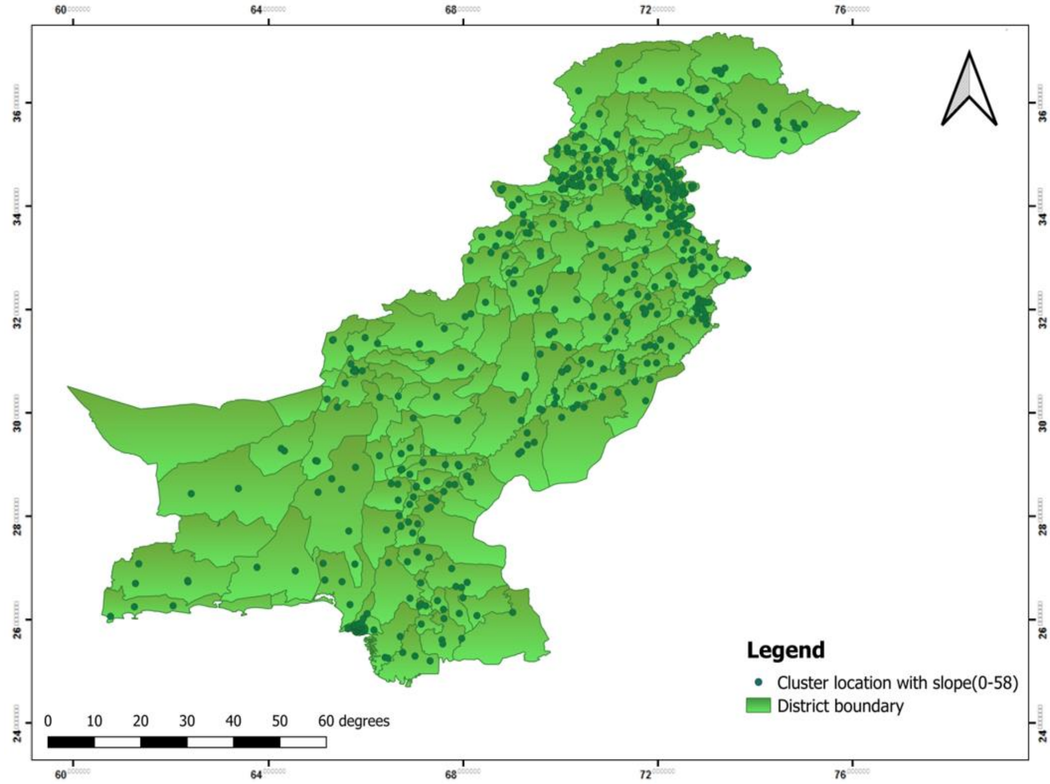

Figure 1. Location and slope of clusters / enumeration blocks

Source: PDHS and Pakistan administrative and slope data from DIVA-GIS and ALOS-JAXA