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Improved Drinking Water, Healthier Children? Evidence from Pakistan

Rashid Javed*

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Abstract

One of the United Nations' sustainable development goals is to ensure the availability of improved drinking water for everyone. In this study, we examine the association between access to improved drinking water at the district level and child nutritional outcomes in Pakistan. In this study, we employ district-level unbalanced panel data from Pakistan from various rounds of PSLM and MICS compiled by the Data4Pakistan, Pakistan District Development Portal. We examine the impact of the percentage of population in a given district with access to clean drinking water on the percentage of stunted, underweight and wasted children in the district. The analysis proceeds in two steps. In the first step, we explore the spatial distribution of improved drinking water coverage and child development outcomes across districts. In the second step, we study their relationship by employing standard panel estimation methods and controlling for district characteristics. Our spatial analysis reveals large disparity among districts and provinces in terms of improved drinking water coverage and child nutrition. The availability of improved drinking water varies between a low of 12% and nearly 100%, with districts in Balochistan and Sindh being the most affected. The estimation results indicate that there is a significant association between accessibility of improved drinking water and child development outcomes. The effect is significant for child stunting and underweight but not on child wasting. A 1% increase in the access to improved drinking water in the district is associated with 9 to 20% decrease in the prevalence of child stunting and underweight. The impact appears to be stronger in rural districts. These findings are robust to alternate empirical strategies. This is the first such study to examine the provision of improved drinking water at the district level in relation to child developmental outcomes in a developing country context.

Key Words: Improved Water; Child Development; Nutrition; Pakistan; District Panel.

JEL codes: Q25, J13, I15, I18, C23, C13, O53

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1 Introduction

Ensuring availability of clean water for all is one of the United Nations' sustainable development goals (SDG) (United Nations General Assembly, 2015). About 2.1 billion people across the world still do not have access to clean water (Ritchie & Roser, 2021; WHO, 2019). Millions of people suffer from diseases caused by polluted water, such as diarrhoea, typhoid and cholera (Usman et al., 2019). In 2017, 1.2 million people died due to unsafe drinking water (Ritchie & Roser, 2021). Water-borne diseases are a major source of child mortality as 6000 children die every day due to lack of clean drinking water and inadequate sanitation (Khalid et al., 2018). A sizeable empirical literature has analysed the welfare and health benefits of improved or clean water. Studies such as Brainerd & Menon (2014), Cairncross et al. (2010), Kumar & Vollmer (2013), Lee et al. (1997), Usman et al. (2019) and Zahid (2018) found a significant link between clean water and sanitation facilities with child mortality and diarrhea. Cross-country panel studies such as Fink et al. (2011), Haller et al. (2007) and Headey & Palloni (2019) look for health impact of clean water availability.

In populous developing countries such as Pakistan, adequate access to improved drinking water remains a challenge. Pakistan is the fifth most populous country in the world with a population of 235 million (World Bank, 2022). According to Ritchie & Roser (2021), only 35.84 percent of the country's population has access to safely-managed drinking water. Around 40 deaths per 100,000 people occur in the country every year due to lack of clean water (Ritchie & Roser, 2021). Similarly, even though the nutrition status of the children has improved over time, Pakistan's child development indicators remain below than the regional average. Figure 1 shows child nutrition status in Pakistan using the nationally representative Pakistan Demographic and Health Survey (PDHS). According to PDHS 1990-91, 49% of children under the age of 5 were stunted, 40% were underweight, and 9% were wasted. By 2012, these figures had dropped to 44%, 29% and 10% respectively (PDHS 2012-13, and by 2017 had further decreased to 38%, 23% and 7%, respectively (PDHS 2017-18).

[Figure 1]

There is some empirical evidence at the individual or household level for a relationship between access to improved drinking water and child health outcomes in Pakistan (Murtaza et al., 2015; Saheed et al., 2021, 2022; Zahid, 2018). Murtaza et al (2015) found lack of clean water to be an important determinant of diarrhoea among Pakistani

children. In another study, Zahid (2018) find the impact of lack of clean water availability on the prevalence of water borne diseases in Pakistan. Similarly, two studies by Saheed et al. (2021, 2022) examined household-level data from the Pakistan Demographic and Health Survey (PDHS) 2017-18 and found a significant association between the household's drinking water source and child malnutrition. There is also some evidence for improvement in access to drinking water and children's later life outcomes in Pakistan. For instance, Rauniyar et al (2011) show that improved water availability enhances girls' high school attendance and increases the labour force participation and hours available for work.

The literature so far has studied the question at the cross-country or household or individual level, and there is little focus on sub-national or municipal level. This is despite the fact that the provision of improved drinking water is generally the responsibility of local governments. In Pakistan, for instance, water management and service delivery is the responsibility of local bodies with the assistance of the provincial governments. In urban areas, Tehsil Municipal Authorities (TMAs) are responsible for water services. Some cities have Water and Sanitation Agencies (WASAs), which are also responsible for operation and maintenance. In the province of Punjab, community-based organizations (CBOs) are responsible for rural water supply. The provincial Public Health Engineering Departments (PHEDs) install drinking water supply projects, primarily in rural, and in some cases, urban communities.

In this study, we examine the relationship between access to improved drinking water and child nutrition outcomes by using district level panel data for Pakistan's 117 administrative districts for the time period between 2010 and 2018. To the best of our knowledge, this is the first such study at the district level in Pakistan. We use data from district-representative household surveys such as Pakistan Social and Living Standards Measurement Surveys (PSLM) and Multiple indicators Custer Surveys (MICS) compiled by the Data4Pakistan, Pakistan District Development Portal, and examine three aspects of child development in the country, namely the percentage of children stunted (i.e. at least 2 standard deviation below the median height for age), percentage of children underweight (i.e. at least 2 standard deviation below the median weight for age) and percentage of children wasted (i.e. at least 2 standard deviation below the median weight for height).

The analysis proceeds in two steps. In the first step, we explore the spatial distribution of improved drinking water coverage and child nutrition across districts. We observe a

large disparity among districts and provinces in terms of clean water coverage and child nutrition. The majority of districts with less access to clean water and higher prevalence of child stunting, child underweight, and child wasting are located in Balochistan province. In the second step, we analyse the empirical association between improved drinking water availability and child development at the district level. We find that children in districts with higher access to improved drinking water are 9 to 20% less likely to be stunted or underweight. We do not observe this statistically significant association with child wasting. We check the robustness of our baseline estimations by including additional controls and employing alternate econometric techniques. The result of these checks remained comparable to the baseline estimates.

The paper is organized as follows: Section 2 briefly overviews the relevant literature. Section 3 describes the dataset and empirical methodology. Spatial distribution and empirical findings are reported in Section 4. Section 5 reports the robustness checks. Section 6 concludes and discusses possible implications of the findings.

2 Literature Review

There is a burgeoning literature on the developmental impacts of clean water availability in developing and developed countries. Some studies linked clean water with different diseases and illness. In a meta-analysis of 144 studies, Esrey et al (1991) reported that access of clean water facilities are important in reducing the rates of ascariasis, diarrhoea, schistosomiasis, trachoma, morbidity, mortality and the severity of hookworm infection. Haller & Hutton (2004) estimated the costs and health benefits of clean water at the global level by considering the ten World Health Organization (WHO) sub-regions. They found that clean water interventions are cost-effective in most sub-regions, and concluded that improvement in water facility brings improvement in health and significantly contributes to the household economy. Cairncross et al (2010) found a 17% reduction in risk of diarrhoea with improved water availability. Similarly, Usman et al (2019) examined the association between drinking water and diarrhoea among under-five children in Ethiopia using primary household survey data, and found that improved drinking water reduces the risk of diarrhoea. Brainerd & Menon (2014) found that exposure to agrichemicals in water, specifically from fertilizers, is associated with increased infant mortality and neo-natal mortality in India.

A few studies examine the effect of clean water availability on child health at the cross-country level. Fink et al (2011) merged 171 available Demographic and Health Surveys (DHS) of 70 low- and middle-income countries over the period 1986–2007 to examine the relationship between child health and access to clean water. They found a lower risk of diarrhoea and mild or severe stunting with access to improved water. In another study, Headey & Palloni (2019) used DHS datasets from 59 countries and constructed a panel of 442 regions to analyse the effect of access to clean water and sanitation on child health outcomes. They found that availability of piped water at the home predicts reductions in child stunting.

A handful of studies have addressed the issue of improved drinking water availability in Pakistan. For example, Khalid et al (2018) assessed the public perception of drinking water quality and safety in district Vehari, Punjab, Pakistan. Their results showed that 48.6% of the respondents were dissatisfied with the drinking water quality of their area. Fida et al (2023) reported that bacteriological contamination such as coliforms, toxic elements like arsenic, iron, nickel, chloride, fluoride, mercury and pesticides were found in both surface water and groundwater and were the major causes of waterborne diseases in Pakistan. Ahmed et al (2023) found that drinking water in the southern province of Pakistan exceeded the World Health Organization (WHO) permitted limit of arsenic and iron. Similarly, Khan et al (2013) examined the drinking water quality and health risks in the Charsadda district. They found that polluted water with coliform bacteria is the main source of waterborne diseases like gastroenteritis, dysentery, diarrhea and viral hepatitis among the surveyed households. According to Kanwa et al (2015), consumption of contaminated drinking water in the Balochistan province is associated with a range of waterborne illnesses including diarrhoea, gastroenteritis, typhoid, cryptosporidium infections, giardiasis, intestinal worms, certain strains of hepatitis, and infant mortality linked to waterborne diarrhoea.

3 Data and Methodology

We construct our district-level unbalanced panel dataset from the data compiled by the Data4Pakistan, Pakistan District Development Portal. Launched on March 10, 2020, Data4Pakistan is the first initiative of its kind that provides an open and public access to various development and policy indicators for every district in Pakistan. The dataset is composed of district representative household surveys such as Pakistan Social and

Living Standards Measurement Surveys (PSLM) and Multiple indicators Cluster Surveys (MICS) conducted and produced by the Pakistan Bureau of Statistics and various provincial Bureaus of Statistics, respectively. The dataset contains a number of demographic, health, education and employment statistics as well as information on access to key services like water, electricity and gas. This dataset also contains a number of gender parity indices at the district level.

Our baseline model can be given as follows:

$$Child\ Nutrition_{it} = \beta_0 + \beta_1 Clean\ Water_{it} + \gamma X_{it} + \theta_t + \zeta_p + \epsilon_{it}$$

Where $Child\ Nutrition_{it}$ represents the children's nutrition status in the district i and year t . We use three indicators of child nutrition status, namely the percentage of children stunted, percentage of children underweight and percentage of children wasted in the district i in the year t .

The variable for stunting is defined as the percentage of children under age 5 in the district who fall below minus two standard deviations (moderate and severe stunting) of the median height-for-age of the World Health Organization (WHO) standard. Similarly, underweight is defined as the percentage of children under age 5 in the district who fall below minus two standard deviations (moderate and severe underweight) of the median weight-for-age of the World Health Organization (WHO) standard. Finally, wasting is defined as the percentage of children under age 5 in the district who fall below minus two standard deviations (moderate and severe wasting) of the median weight-for-height of the World Health Organization (WHO) standard.

$Clean\ Water_{it}$ represents access to clean drinking water in the district i and year t . And is defined as the percentage of the population in the given district that has access to clean drinking water. X_{it} is the vector of time-varying district-specific control variables; θ_t is time-fixed effects, ζ_p is province-effects and ϵ_{it} is the error term respectively.

We include a number of controls including full immunization, mother's early marriage, child dependency ratio, adult literacy, poverty rate, labour force participation and the share of urban population in the district i in the year t .

Our final unbalanced panel consists of 117 districts²³ spanning the time period from 2010 to 2018, with a total of 462 observations. The definition and summary statistics of the variables are reported in table A1 (appendix). The table shows that 46.05% children are stunted, 36.42% are underweight and 15.45% are wasted in our unbalanced district

² The list of districts is provided in Table A4 in the appendix.

³ We impute the missing values in districts for later years by following the approach of Cox (2023).

panel sample.⁴ 76% of the population, on average, has access to improved drinking water facility. 63.89% of children aged 12-23 months in the district are reported to be fully immunized. On average, 38.19% of the population lives below the official national poverty line.

We employ a number of panel estimation methods to estimate our baseline model. First, as benchmark, we carry out pooled ordinary least squares (OLS) estimation. However, its estimated coefficient of interest can be inconsistent in the presence of unobserved heterogeneity. If there are unobserved effects that are independent of the covariates, then OLS is consistent but inefficient. If the unobserved effects are correlated with the covariates, pooled OLS suffers from omitted variable bias. One way to overcome this issue is to employ random-effects (RE) specification. The consistency of a random-effects specification depends on the assumption of independence of the unobserved effects. The fixed-effects (FE) method allows unobserved effects to be correlated with the covariates and removes unobserved effects. In this study, we employ both specifications and use Hausman test to know which estimation is more appropriate. In addition, we incorporate the time and province fixed effects to account for variation over time and for cross-province variation. The correlation matrix and variance Inflation factor (VIF) of the sample are reported in Tables A2 and A3 in the appendix. The mean VIF value of our model is 2.57, implying that multicollinearity should not be an issue. We examined serial correlation among variables using the portmanteau test developed by Jochmans & Verardi (2020). The test value indicates that there is no autocorrelation in the model. We check the robustness of our baseline estimates by using additional controls and alternate estimation techniques. We used robust standard errors in all sets of regressions.

4 Results

4.1 Spatial Distribution

Figures 2-5 present the spatial distribution of improved drinking water coverage and child nutrition status across districts. Huge disparities can be observed among districts

⁴The child nutrition data used in this dataset based on MICS are not comparable with the PDHS data used in Figure 1 above. Unlike MICS, PDHS data are representative at the national level but not at the district level. However, DHS are carried out throughout the country in the same year and therefore provide accurate country-level aggregates. In contrast, MICS are carried out by various provinces in different years which makes country-level aggregates in a given year incomplete.

and provinces in terms of improved water access and child nutrition. We find that the province of Balochistan is more deprived in comparison to other provinces of the country (Figure 2). Eight out of ten districts with the lowest access to improved drinking water are located in this province, with the availability of water as low as 12.68% in the Kohlu district. In contrast, seven out of ten districts with the highest access to clean water are located in the Punjab province. The districts with the lowest access to improved drinking water include Kohlu, Musakhel, Kohistan, Tharparkar, Dera Bugti, Sheerani, Jhal Magsi, Kachhi, Ziarat and Barkhan. At the other end, the districts with near universal access to improved drinking water include Chiniot, Okara, Sheikhpura, Mandi Bahauddin, Sahiwal, Matiari, Lahore, Sialkot, Hafizabad, Muzaffargarh, Naushahro Feroze, Bhakkar, Ghotki, Narowal, Gujrat, Gujranwala, Shikarpur, and Layyah.

[Figure 2 and 3]

Figure 3 shows the spatial distribution of the prevalence of child stunting across districts. The prevalence varies widely across districts with a minimum of 13.08% in Nushki and a maximum of 89.69% in Kech. Child stunting is high in the majority of districts of Balochistan and Sindh provinces, with the ten worst-affected districts with more than 60% incidence of child stunting located in the two provinces. The ten districts with higher incidence of child stunting are Jacobabad, Umerkot, Kashmore, Badin, Dera Bugti, Nasirabad, Las Bela, Shangla, Gwadar, and Kech. In contrast, eight out of the ten districts with the lowest prevalence of child stunting are located in Punjab with the two remaining districts located in Khyber-Pakhtunkhwa and Balochistan. The districts are Nushki, Rawalpindi, Haripur, Jhelum, Attock, Gujrat, Chakwal, Sialkot, Gujranwala and Lahore.

[Figure 4]

Figure 4 shows district-wise spatial distribution of the prevalence of child underweight. The patterns are similar to those of stunting, with a minimum of 7.78% in Karak and a maximum of 83.93% in Musakhel. Here, among the ten worst-affected districts, six are located in Balochistan (Musakhel, Zhob, Kachhi, Barkhan, Kohlu and Dera Bugti) while four are situated in Sindh (Tharparkar, Umerkot, Badin and Tando Muhammad Khan). The top ten districts with the lowest incidence of underweight children are Karak, Abbottabad, Chitral, Tank, Haripur, Malakand PA, Kech, Kohat, Mardan, and Nushki.

Figure 5 shows the spatial distribution of the prevalence of child wasting across districts. The findings are unsurprising as regional and districts disparities are similar.

The prevalence of wasting ranges from a low of 0% in Panjgur to a high of 33.64% in Kachhi. As before, most of the districts with high prevalence of child wasting are found in Balochistan. The districts with the highest prevalence of child wasting are Kachhi, Musakhel, Tharparkar, Ziarat, Zhob, Jaffarabad, Sohbatpur, Pishin, Mirpur Khas and Barkhan. The top ten districts with the lowest prevalence of child wasting are Panjgur, Kech, Chitral, Buner, Bannu, Malakand PA, Mardan, Charsadda, Kharan, and Karak.

[Figure 5]

4.2 Estimation Results

We begin by graphically analyzing the correlation between improved drinking water accessibility and child nutrition status⁵. We observe that there is a negative correlation between improved drinking water access and child nutrition at the district level. Children of districts with high access to improved drinking water have lower prevalence of stunting, underweight and wasting.

[Table 1]

Tables 1, 2 and 3 report the results of our baseline econometric specifications. Table 1 shows the results for the relationship between access to improved drinking water and child stunting. The first three columns of this table report the coefficients and standard errors of the pooled OLS, random-effects and fixed-effects estimations. We see a negative and significant association. A 1% increase in the access to improved drinking water is associated with 12 to 13% decrease in the prevalence of stunting among the children. The fourth column displays the estimated coefficient and robust standard errors of the time and province fixed effects estimations. The estimated coefficient of interest again shows a negative and significant association between improved drinking water access and child stunting. A 1% increase in clean water access associated 9% decrease in the prevalence of child stunting.

[Table 2]

Table 2 reports the results of panel regressions for child underweight. The findings are qualitatively similar to those presented above. Columns 1–3 provide results of pooled OLS, random-effects and fixed-effects estimations. The sign of all the three coefficients is negative, suggesting the existence of a negative relationship between improved drinking water access and child underweight. A 1% increase in clean water access is associated up to 13% decrease in the prevalence of child underweight. The last column

⁵ The graphs are available in the appendix.

of this table reports the result for the estimation including time and province fixed effects. As before, access to clean water has a negative and significant association with the prevalence of child underweight, with a coefficient of 0.20 significant at the 5% level of significance.

[Table 3]

Finally, Table 3 represents the results of panel regressions for child wasting. Columns 1 to 3 show results for pooled OLS, random-effects and fixed-effects estimations, while column 4 reports the estimates with time and province fixed effects. In all the four panel specifications, we fail to find a significant association between access to improved drinking water and child wasting. The finding suggests that access to clean water does not play a role in reducing child wasting.

Here, we need to note an important factor: In developing countries, public spending is often more inclined towards the cities due to urban bias. In Pakistan, rural areas are more deprived than the urban population (Padda & Hameed, 2018). In our sample, rural districts (i.e. those with below average population residing in urban centers) have lower access to improved water (75.20%) compared to the urban districts (86.73%). At the same time, prevalence rates of child stunting, underweight and wasting are much higher (46.51 % vs 43.35 %, 36.87 % vs 33.77 % and 15.51 % vs 15.11 %, respectively).

This suggests that the impact of increased supply of improved drinking water in the rural districts may affect child nutrition outcomes differently than it may do in more urbanized districts. We account for this possibility by comparing the relationship by the subsamples of rural and urban districts, i.e. those with below and above 35% of the population living in urban centers. The results for the two subsamples show a clear divergence between the rural and the urban districts. In the rural districts, the impact of access to improved drinking water on stunting and underweight is strong and statistically significant, with a 1% increase in access to improved water associated with a 13% reduction in stunting and 21% reduction in underweight. In contrast, the impact in the urban districts is not significant.

[Table 4]

Overall, our findings show a positive impact of enhancing the supply of clean drinking water on child stunting and underweight and suggest that improving access to drinking water by local bodies can significantly improve child nutrition outcomes of the district. These district-level panel findings are consistent with those reported in individual-level

and household-level studies from Ethiopia and Pakistan, such as Tadesse et al. (2018), Ahmad et al. (2020) and Usman et al. (2019).

5 Robustness Checks

In this section, we assess the robustness of our baseline results through additional checks.

5.1. Additional health-related controls

According to Usman et al. (2019), access to improved drinking water alone is not sufficient to lower the health risk because improved sanitation is also a very important driver of health outcomes. Similarly, Kumar and Vollmer (2013) analyzed nationally representative data from India and observed a 2.2 percentage point decrease in the incidence of diarrhea among children residing in households equipped with improved sanitation facilities. We account for this possibility by including the percentage of population in the district that has improved sanitation facility as additional control in our base line model. The association between improved drinking water availability and child stunting and underweight is again found to be significant and negative (Table 5, Columns 1-3). A 1% increase in improved drinking water access is associated with 10 to 20 % decline in prevalence of child stunting and underweight. Again, access to improve drinking water has no significant association with child wasting.

[Table 5]

A second additional healthcare indicator that we consider is the access to healthcare services. Access to healthcare facilities is an important determinant of health outcomes in any society. Equitable and easy access to healthcare services can lead to a range of positive health outcomes. Distance to health facilities plays a pivotal role in utilization of healthcare services (Feikin et al., 2009; Müller et al., 1998; Noor et al., 2003). For instance, Schoeps et al. (2011) showed a strong significant effect of distance to the closest health facility on various child health outcomes in Burkina Faso.

We define the indicator of access to healthcare as the percentage of population in the district with access to a health clinic or hospital within 15 minutes of their dwelling. The estimation results shown in columns 4-6 of Table 5 are consistent and support the baseline findings. The impact on child stunting and underweight is similarly significant and beneficial, with a 1% increase in access to improved water in the district associated with 9% and 20% decrease in the prevalence of the two, respectively.

The third additional control that we include is access to clean cooking fuel as a proxy for indoor air pollution. Studies such as Irfan et al. (2023) showed the causal impact of using unclean cooking fuel on child health. We define access to clean cooking fuel as the percentage of population in the district whose main source of fuel to cook food is electricity or gas. The findings of these estimations (Table 5, Columns 7-9) are again comparable to our baseline estimates.

5.2. Additional district characteristics

By including additional variables related to district characteristics, our model can better account for the diversity among districts, allowing for a more nuanced analysis. This goes beyond establishing a broad association between improved drinking water and better nutrition, as it helps identify the unique priorities and challenges associated with specific district endowments. To address this, we included three controls related to district characteristics: agriculture production, employment in agriculture (% of total employment), and access to transportation (% of population within 15 minutes of public transportation).

The first of these indicators stands for the production, and thus the degree of prosperity of the district, the second proxies its level of development, and the third indicates its connectivity. The estimations carried out by individually including these variables (Table 6) align with the baseline estimates, reinforcing the robustness of the association between improved drinking water and child development outcomes.

[Table 6]

5.3. Alternative techniques

We estimate the baseline model by employing two alternative empirical techniques, including Generalized Least Squares (GLS) and Panel Corrected Standard Errors (PCSE) estimators. The GLS estimator permits estimation in the presence of autocorrelation within panels, cross-sectional correlation, and heteroskedasticity across panels (StataCorp, 2019), while the PCSE estimator can estimate linear cross-sectional time series models, and considers the disturbances to be by default heteroskedastic and contemporaneously correlated across panels (Greene, 2012). The association between access to improved drinking water and child nutrition outcomes is found to be similar to the baseline estimations (Table 7), with the impact on stunting and underweight significant at 1% with the two estimators.

[Table 7]

5.4. Bootstrapping

Finally, we estimate the regression models by incorporating bootstrap standard errors. According to Gonçalves & White (2005), inferences in small samples based on bootstrap standard errors are comparatively more accurate than those based on asymptotic closed form standard error estimates. Our estimates with bootstrapped standard errors, shown in Table 8, again, are similar to the baseline estimates with the coefficients of child stunting and underweight both significant at 1%.

[Table 8]

6 Conclusion

Ensuring the availability of improved and clean drinking water for all is one of the sustainable development goals (SDG). In this study, we investigated the relationship between improved drinking water access and child nutrition outcomes in Pakistan using district-level unbalanced panel data and spatial distribution analysis. We observed large disparity across districts and provinces in terms of improved drinking water availability and child nutrition. Employing different panel specifications, we found that access to improved drinking water has a significant association with the child nutrition status at the district level in Pakistan. Children of districts with higher access to clean drinking water are less likely to be stunted or underweight, highlighting the need to increase the availability of clean drinking water by the local governments. In contrast, the association with child wasting lacks statistical significance, suggesting the possibility that the impact of improved water provision does not alter the severity of deprivation that wasting represents. These patterns are found to be stronger in the rural districts, reflecting the fact that the need to provide improved drinking water and to ameliorate child nutrition outcomes is that much greater in rural areas. These findings underscore the pivotal role of improved drinking water access at the district level in enhancing the child nutrition outcomes. The findings emphasize the urgency of addressing regional disparities in improved drinking water availability, and call for targeted interventions to ensure that every child has the opportunity to grow in safe, healthy environment and attain their full potential in life.

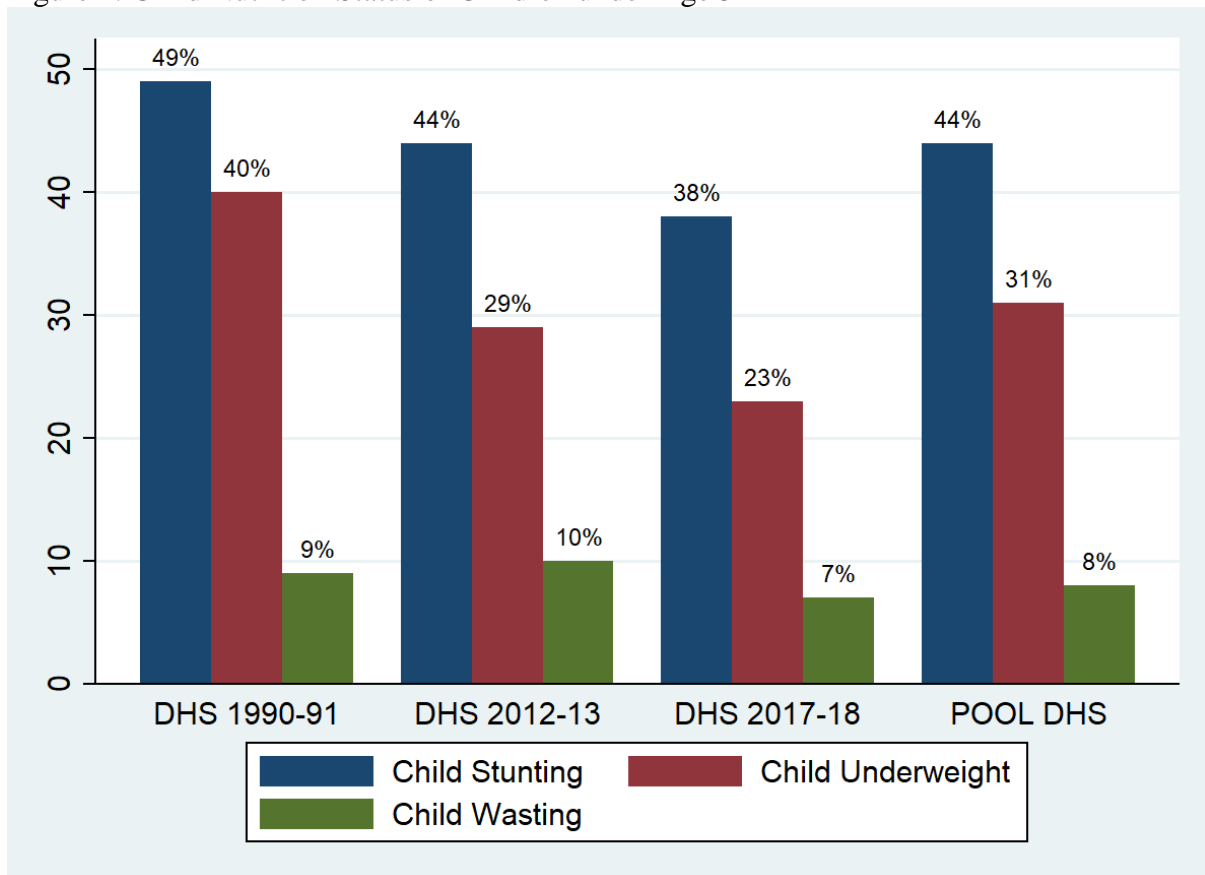
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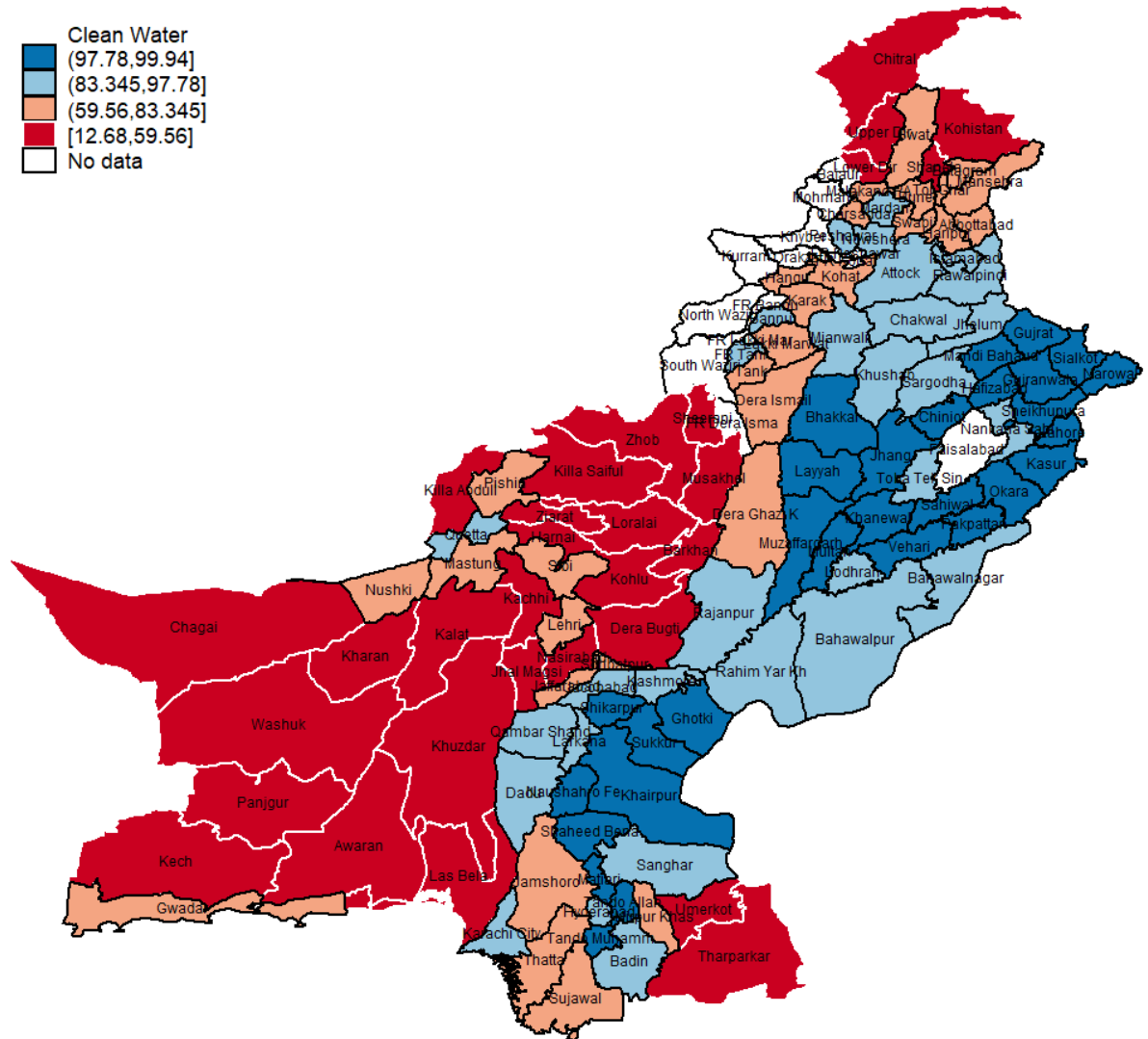
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Figure 1: Child Nutrition Status of Children under Age 5



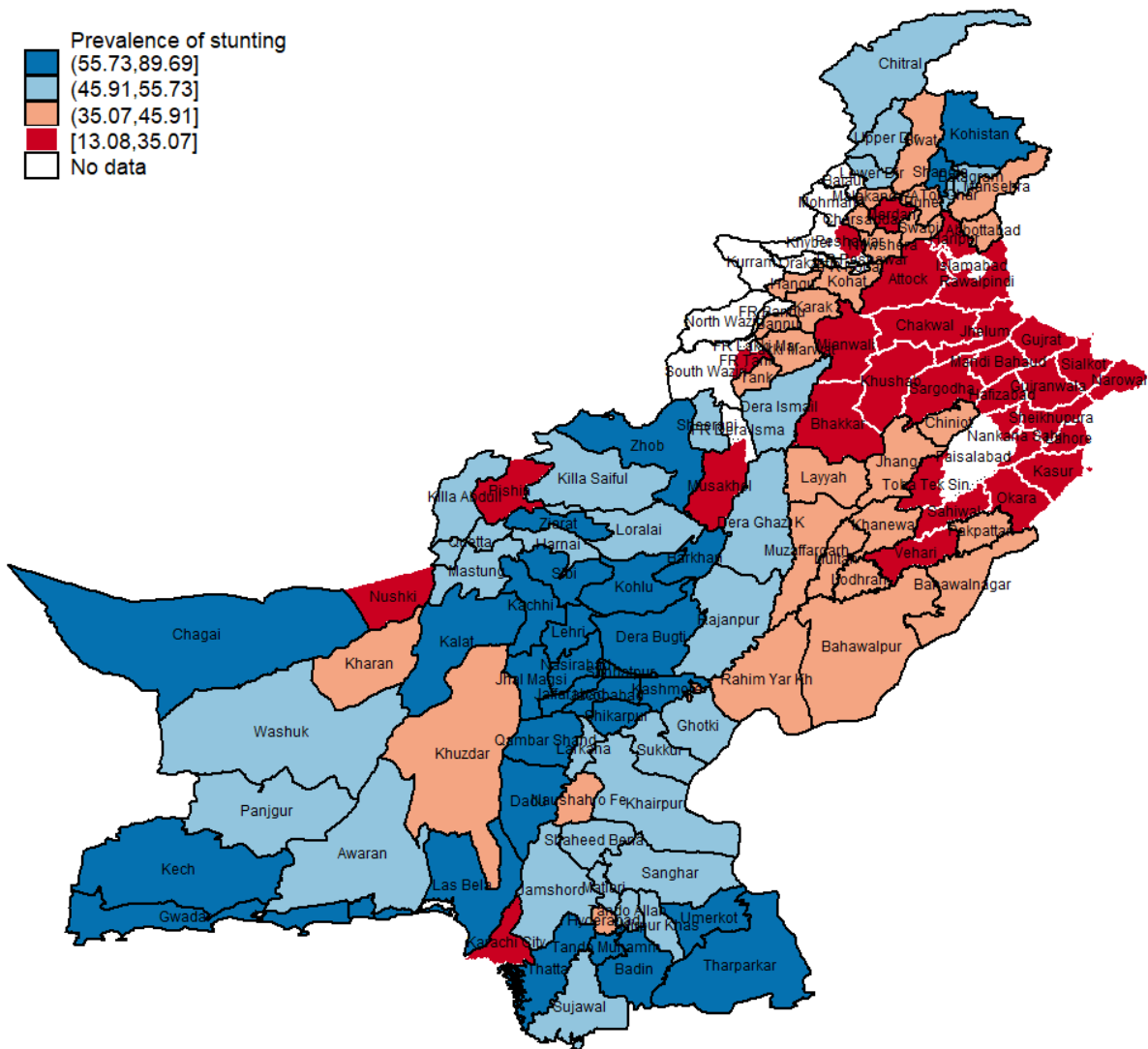
Source: Author's calculations using PDHS Surveys (1990-91, 2012-13, 2017-18).

Figure 2: Spatial distribution of improved drinking water coverage by district



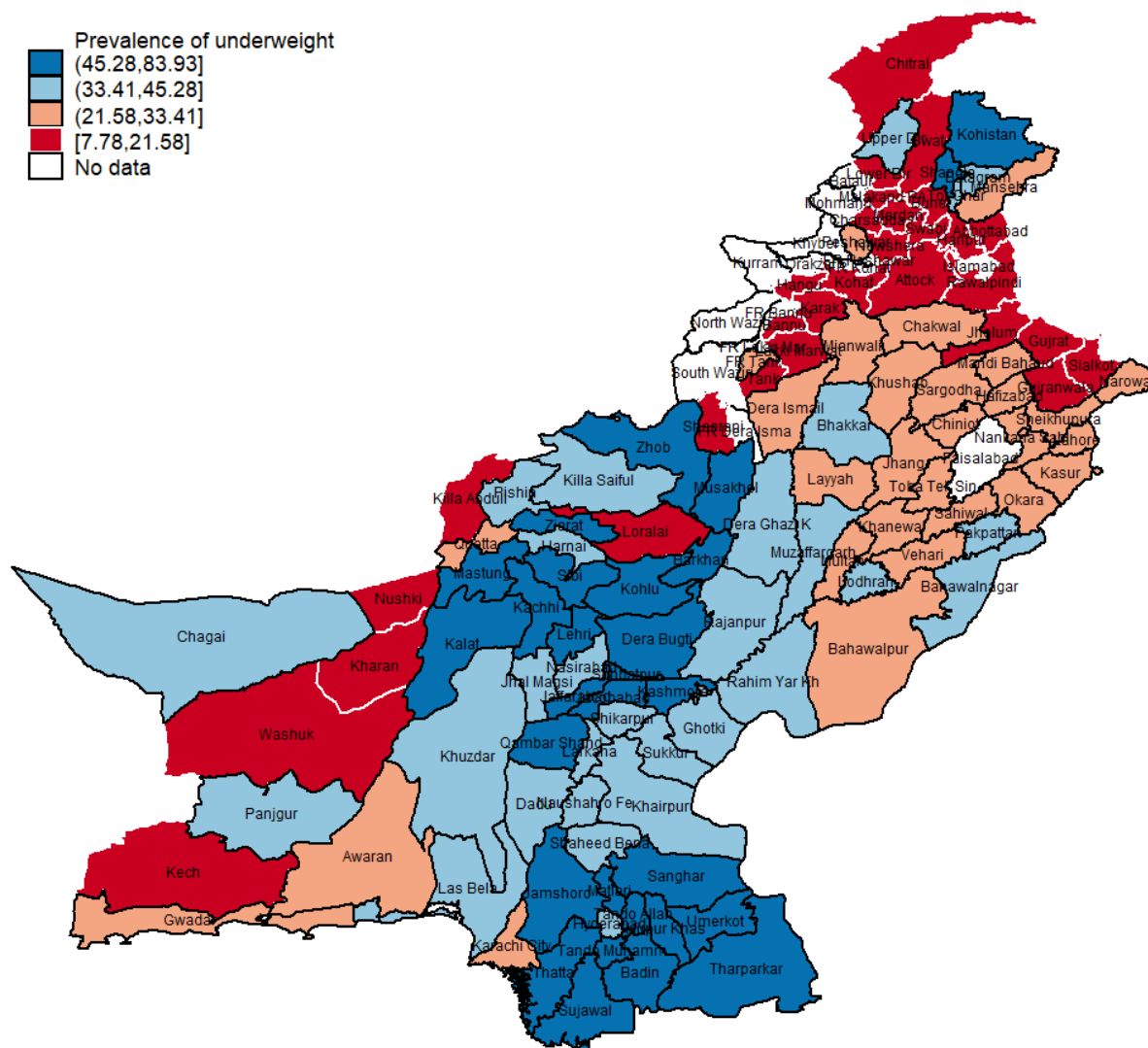
Source: Author's calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Figure 3: Spatial distribution of prevalence of child stunting by district



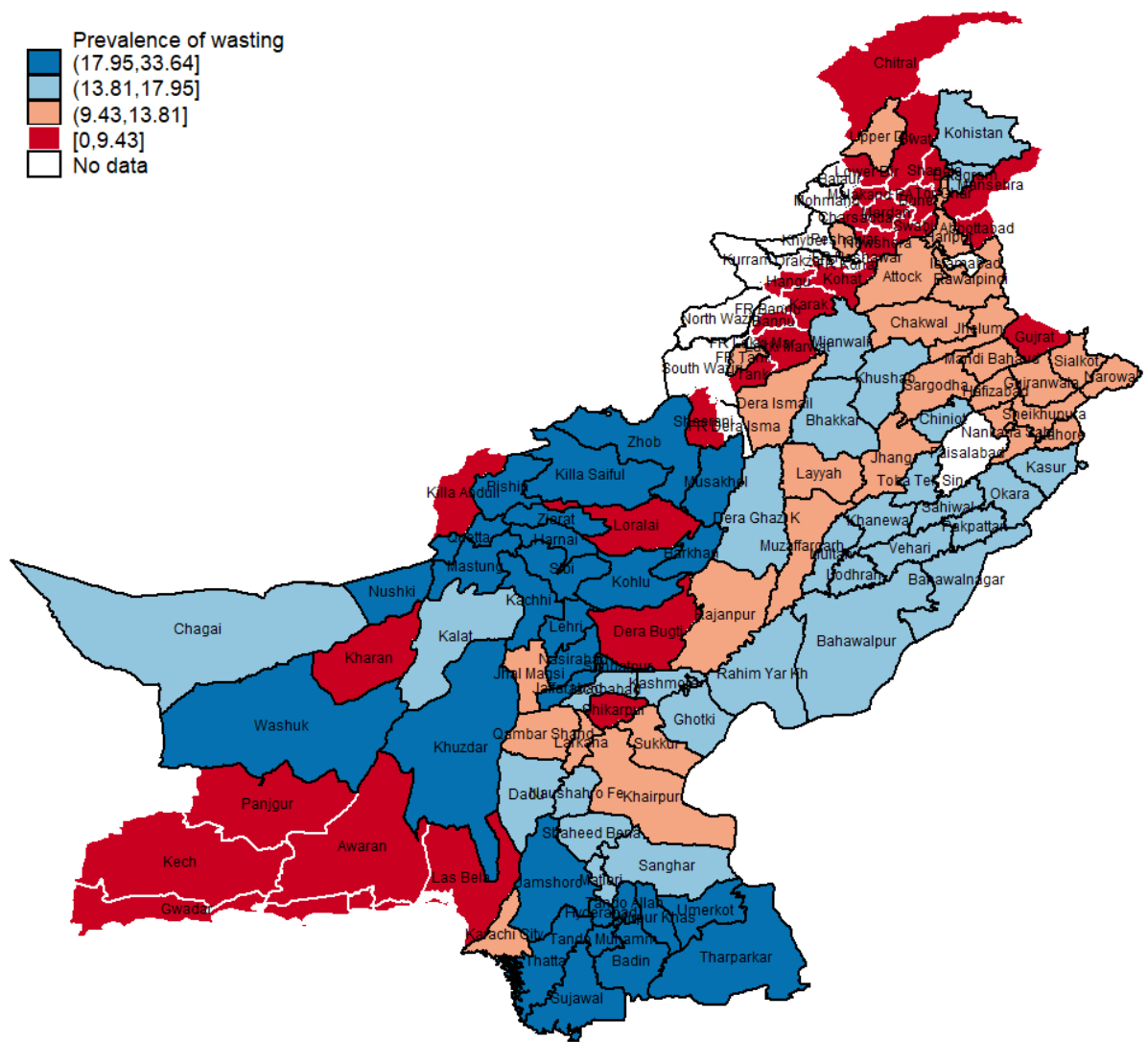
Source: Author's calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Figure 4: Spatial distribution of prevalence of child underweight by district



Source: Author's calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Figure 5: Spatial distribution of prevalence of child wasting by district



Source: Author's calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Table 1: Improved drinking water and child stunting

VARIABLES	(1) Child Stunting	(2) Child Stunting	(3) Child Stunting	(4) Child Stunting
Improved Drinking Water	-0.128*** (0.028)	-0.128*** (0.015)	-0.131*** (0.015)	-0.093* (0.037)
Constant	16.883** (8.248)	16.883 (11.390)	16.369 (11.235)	28.474*** (5.871)
Observations	462	462	462	462
Controls	YES	YES	YES	YES
Hausman Specification Test (P-Value)			0.000	
Time Fixed Effects	NO	NO	NO	YES
Province Fixed Effects	NO	NO	NO	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Column 1 shows Pooled OLS estimation. Columns 2 and 3 show Random- and Fixed-effects estimations, respectively. Column 4 shows the model including time and province fixed effects, respectively. Hausman specification test, which compares the random-effects model with the fixed-effects model, finds that the former is inconsistent. Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Table 2: Improved drinking water and child underweight

VARIABLES	(1) Child Underweight	(2) Child Underweight	(3) Child Underweight	(4) Child Underweight
Improved Drinking Water	-0.126*** (0.044)	-0.126*** (0.044)	-0.132** (0.046)	-0.209** (0.054)
Constant	3.058 (12.348)	3.058 (18.975)	2.536 (18.330)	28.468* (13.256)
Observations	462	462	462	462
Controls	YES	YES	YES	YES
Hausman Specification Test (P-Value)			0.000	
Time Fixed Effects	NO	NO	NO	YES
Province Fixed Effects	NO	NO	NO	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Column 1 shows Pooled OLS estimation. Columns 2 and 3 show Random- and Fixed-effects estimations, respectively. Column 4 shows the model including time and province fixed effects, respectively. The Hausman specification test, which compares the random-effects model with the fixed-effects model, finds that the former is inconsistent. Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Table 3: Improved drinking water and child wasting

VARIABLES	(1) Child Wasting	(2) Child Wasting	(3) Child Wasting	(4) Child Wasting
Improved Drinking Water	-0.006 (0.023)	-0.006 (0.013)	-0.007 (0.014)	0.000 (0.026)
Constant	5.472 (6.387)	5.472 (5.362)	4.529 (5.234)	14.939** (3.519)
Observations	462	462	462	462
Controls	YES	YES	YES	YES
Hausman Specification Test (P-Value)			0.0001	
Time Fixed Effects	NO	NO	NO	YES
Province Fixed Effects	NO	NO	NO	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Column 1 shows Pooled OLS estimation. Columns 2 and 3 show Random- and Fixed-effects estimations, respectively. Column 4 shows the model including time and province fixed effects, respectively. The Hausman specification test, which compares the random-effects model with the fixed-effects model, finds that the former is inconsistent. Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Table 4: Improved drinking water and child development outcomes- Rural and urban subsamples

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Child Stunting		Child Wasting		Child Underweight	
	Below 35%	35% and Above	Below 35%	35% and Above	Below 35%	35% and Above
Improved Drinking Water	-0.132**	-0.132	-0.212**	-0.101	0.006	0.035
	(0.039)	(0.127)	(0.054)	(0.072)	(0.027)	(0.100)
Constant	27.130**	55.207***	24.048	12.626	14.504***	-11.854
	(6.298)	(8.693)	(15.451)	(10.268)	(2.611)	(11.546)
Observations	395	67	395	67	395	67
Controls	YES	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES	YES
Province Fixed Effects	YES	YES	YES	YES	YES	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Column 1–6 shows the results for rural districts (i.e. those with less than 35% urban population) and urban districts (i.e. those with above 35% urban population). Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Table 5: Improved drinking water and child development outcomes- Additional Health related Indicators

VARIABLES	(1) Child Stunting	(2) Child Underwei ght	(3) Child Wastin g	(4) Child Stunting	(5) Child Underwei ght	(6) Child Wastin g	(7) Child Stuntin g	(8) Child Underwei ght	(9) Child Wasting
	Improved Sanitation			Health Care Access			Clean Cooking Fuel		
Improved Drinking Water	-0.107*	-0.202**	0.004	-0.093*	-0.207**	0.001	-0.092*	-0.210**	-0.001
	(0.040)	(0.054)	(0.025)	(0.037)	(0.054)	(0.026)	(0.039)	(0.050)	(0.023)
Constant	36.301*	24.443	12.645	28.654*	28.854*	15.347	28.432	28.534*	14.988*
	**		**	**		**	**		**
	(5.213)	(14.112)	(3.924)	(5.917)	(13.528)	(3.459)	(6.716)	(13.235)	(3.099)
Observations	462	462	462	462	462	462	462	462	462
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Columns 1-9 show the results with additional controls in the baseline model. All regression models include time and province fixed effects. Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Table 6: Improved drinking water and child development outcomes- Additional District Characteristics

VARIABLE	(1) Child Stunting	(2) Child Underweigh t	(3) Child Wasting	(4) Child Stunting	(5) Child Underweigh t	(6) Child Wastin g	(7) Child Stunting	(8) Child Underweigh t	(9) Child Wastin g
	Agriculture Production			Employment in Agriculture			Access to Transportation		
Improved Drinking Water	-0.078***	-0.250***	-0.046	-0.067**	-0.233***	-0.033	-0.056***	-0.223***	-0.041
	(0.013)	(0.033)	(0.031)	(0.017)	(0.037)	(0.035)	(0.006)	(0.032)	(0.032)
Constant	41.294**	23.451*	12.486*	30.792*	11.617	6.090	50.050**	31.737**	11.225*
	(8.233)	(10.785)	(4.003)	(9.176)	(12.077)	(4.620)	(5.976)	(8.236)	(4.096)
Observations	398	398	398	398	398	398	398	398	398
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020 and District Development report. Columns 1-9 show the results with additional controls in the baseline model. All regression models include time and province fixed effects. Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Table 7: Improved drinking water and child development outcomes- Alternative techniques

VARIABLES	(1) Child Stunting	(2) Child Underweight	(3) Child Wasting	(4) Child Stunting	(5) Child Underweight	(6) Child Wasting
Improved Drinking Water	-0.128*** (0.024)	-0.126*** (0.034)	-0.006 (0.019)	-0.128*** (0.020)	-0.126*** (0.046)	-0.006 (0.020)
Constant	16.883*** (6.419)	3.058 (9.168)	5.472 (5.058)	16.883** (6.802)	3.058 (13.724)	5.472 (4.719)
Observations	462	462	462	462	462	462
Controls	YES	YES	YES	YES	YES	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Column 1–6 show GLS and Panel Corrected Standard Errors estimator results. Robust standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

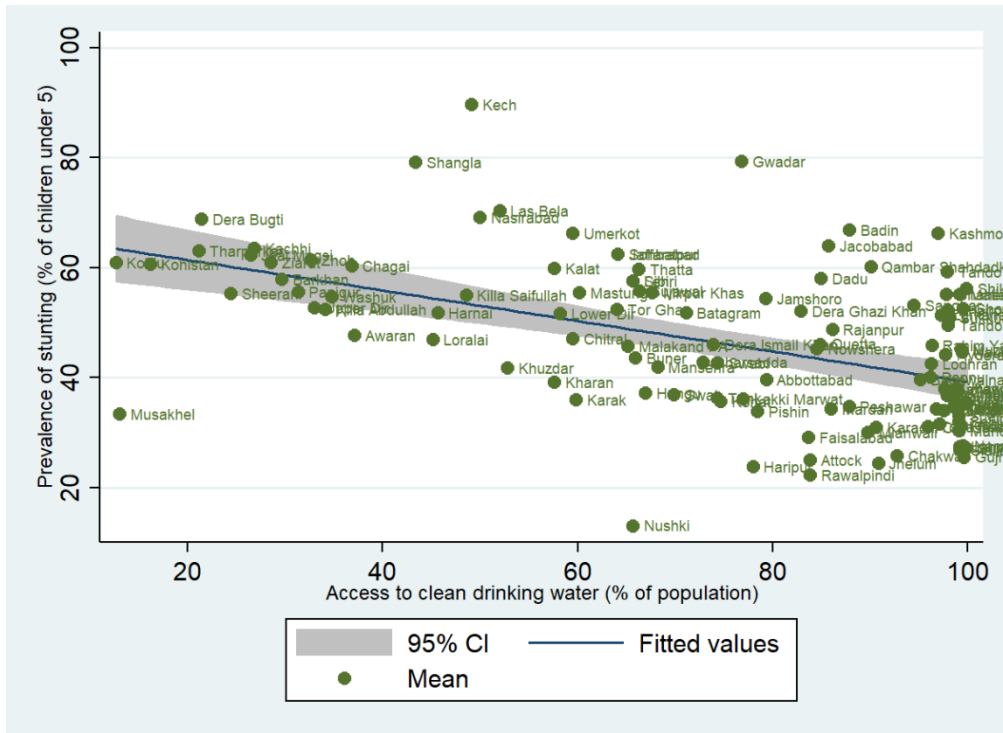
Table 8: Improved drinking water and child development outcomes- Bootstrap standard errors

VARIABLES	(1) Child Stunting	(2) Child Underweight	(3) Child Wasting
Improved Drinking Water	-0.09345*** (0.02545)	-0.20858*** (0.04756)	0.00009 (0.02099)
Constant	28.47444*** (6.23902)	28.46801*** (10.75721)	14.93908*** (3.20941)
Observations	462	462	462
Bootstrap Replications	50	50	50
Controls	YES	YES	YES
Time Fixed Effects	YES	YES	YES
Province Fixed Effects	YES	YES	YES

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020. Columns 1-3 show the results with bootstrapped standard errors. All regression models include time and province fixed effects. Standard errors in parentheses *** p<0.01, ** p<0.05, *p<0.1

Appendix

Figure A1: Scatter plot of improved drinking water and child stunting



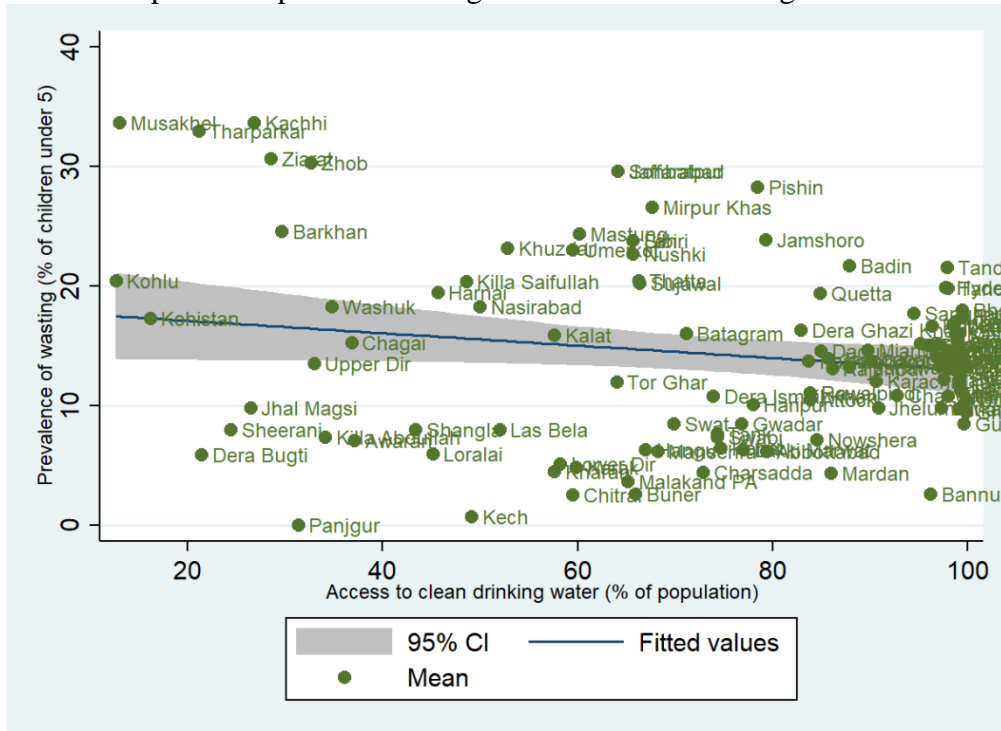
Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Figure A2: Scatter plot of improved drinking water and child underweight



Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Figure A3: Scatter plot of improved drinking water and child wasting



Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Table A1: Descriptive statistics

Variables	Definition	Obs.	Mean	Std. Dev.
Outcome Variables				
Child Stunting (%)	Percentage of children under age 5 in the district, who fall below minus two standard deviations (moderate and severe stunting) of the median height-for-age of the World Health Organization (WHO) standard.	462	46.05	14.46
Child Underweight (%)	Percentage of children under age 5 in the district, who fall below minus two standard deviations (moderate and severe underweight) of the median weight-for-age of the World Health Organization (WHO) standard.	462	36.42	16.00
Child Wasting (%)	Percentage of children under age 5 in the district, who fall below minus two standard deviations (moderate and severe wasting) of the median weight-for-height of the World Health Organization (WHO) standard.	462	15.45	7.70
Variable of Interest				
Improved Drinking Water (%)	The percentage of population in the district that has access to improved drinking water facility. Improved drinking water source includes piped water, hand pump, water motor, tube well, covered well, or filtration plant.	462	76.87	25.79
Controls				
Fully immunized (%)	Percentage of children aged 12-23 months in the district who report being fully immunized. To be considered fully immunized the child must have received the following vaccines at the time of the survey: BCG (one dose), polio (three doses), DPT (three doses), measles (one dose).	462	63.89	28.24
Women's marriage before age 18 (%)	Percentage of women aged 20-24 in the district who were married before age 18.	462	21.71	10.30
Household child dependency ratio (%)	Percentage of dependency ratio in the district. The ratio is defined as the number of child dependents (members younger than 15 years) to the number of members in working-age group (aged 15-64).	462	39.72	6.32
Adult literacy (%)	Percentage of population aged 25 and above in the district who is able to write, read and solve simple mathematical problems.	462	37.57	13.82
Poverty rate (%)	Percentage of population in the district living below the official national poverty line.	462	38.19	14.84
Labor force participation rate (%)	Percentage of working age-population (15-64 years old) in the district that either did any work for monetary return in the last week for at least one hour in any day, or had a business, shop, trade, farm, service institution, or worked as a helper (without payment) for home farm, business, trade, etc., or was looking for a job.	462	50.72	10.24
Urban share of population (%)	Percentage of population in the district who lives in urban areas.	462	23.17	16.38
Additional Controls				
Improved Sanitation (%)	Percentage of population in the district has improved toilet facility for their necessities. Improved toilet facility refers to either flush connected to public sewerage, or flush connected to septic tank	462	37.01	29.30
Health Care Access (%)	Percentage of population in the district that has access to a health clinic or hospital within 15 minutes of their dwelling.	462	40.76	24.75
Clean Cooking Fuel (%)	Percentage of population in the district whose main source of fuel to cook food is electricity or gas.	462	23.75	22.30

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Table A2: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Child Stunting	1.000										
(2) Child Underweight	0.517	1.000									
(3) Child Wasting	0.118	0.714	1.000								
(4) Improved Drinking Water	-0.514	-0.309	-0.092	1.000							
(5) Poverty rate	0.691	0.500	0.288	-0.593	1.000						
(6) Household child dependency ratio	0.585	0.315	0.102	-0.482	0.696	1.000					
(7) Labor force participation rate	0.295	0.407	0.330	-0.036	0.395	0.202	1.000				
(8) Adult literacy	-0.624	-0.394	-0.170	0.615	-0.796	-0.700	-0.320	1.000			
(9) Women's marriage before age 18	0.423	0.299	0.066	-0.043	0.219	0.255	0.304	-0.423	1.000		
(10) Fully immunized	-0.555	-0.341	-0.149	0.579	-0.631	-0.517	-0.221	0.573	-0.197	1.000	
(11) Urban share of population	-0.204	-0.076	0.025	0.424	-0.367	-0.326	-0.173	0.606	-0.249	0.287	1.000

Source: Authors' calculations using Data4Pakistan, Pakistan District Development Portal 2020.

Table A3: Variance Inflation Factors

Variable	VIF	1/VIF
Adult literacy	5.48	0.182590
Poverty rate	4.14	0.241263
Household child dependency ratio	2.27	0.441360
Improved Drinking Water	2.18	0.457958
Fully immunized	1.91	0.523007
Urban share of population	1.74	0.574232
Women's marriage before age 18	1.45	0.688582
Labor force participation rate	1.37	0.728333
Mean VIF	2.57	

Table A4: Districts Included in the Sample

Abbottabad	Gwadar	Killa Abdullah	Muzaffargarh	Shikarpur
Attock	Hafizabad	Killa Saifullah	Nankana Sahib	Sialkot
Awaran	Hangu	Kohat	Narowal	Sibi
Badin	Haripur	Kohistan	Nasirabad	Sohbatpur
Bahawalnagar	Harnai	Kohlu	Naushahro Feroze	Sujawal
Bahawalpur	Hyderabad	Lahore	Nowshera	Sukkur
Bannu	Jacobabad	Lakki Marwat	Nushki	Swabi
Barkhan	Jaffarabad	Larkana	Okara	Swat
Batagram	Jamshoro	Las Bela	Pakpattan	Tando Allah Yar
				Tando Muhammad
Bhakkar	Jhal Magsi	Layyah	Panjgur	Khan
Buner	Jhang	Lehri	Peshawar	Tank
Chagai	Jhelum	Lodhran	Pishin	Tharparkar
			Qambar	
Chakwal	Kachhi	Loralai	Shahdadkot	Thatta
Charsadda	Kalat	Lower Dir	Quetta	Toba Tek Singh
	Karachi			
Chiniot	City	Malakand PA Mandi	Rahim Yar Khan	Tor Ghar
Chitral	Karak	Bahauddin	Rajanpur	Umerkot
Dadu	Kashmore	Mansehra	Rawalpindi	Upper Dir
Dera Bugti	Kasur	Mardan	Sahiwal	Vehari
Dera Ghazi Khan	Kech	Mastung	Sanghar	Washuk
Dera Ismail Khan	Khairpur	Matiari	Sargodha	Zhob
			Shaheed	
Faisalabad	Khanewal	Mianwali	Benazirabad	Ziarat
Ghotki	Kharan	Mirpur Khas	Shangla	
Gujranwala	Khushab	Multan	Sheerani	
Gujrat	Khuzdar	Musakhel	Sheikhupura	