Key Points

- Empirical analysis of sanitation, health, and education using country-level data suggests that sanitation improves child health, increases enrollment, and leads to higher girls' participation in schools.
- Governments should prioritize and focus on the construction of accessible toilets in poor areas and slums, where lack of sanitation exposes many children to various health risks.
- Given that sanitation access improves school enrollment, especially among girls, building sanitation facilities require initiative from the households and school officials themselves, consistent support from local authorities, and designs that cater to girls' needs.
- Behavioral change campaigns and financial support schemes may help address structural constraints in household sanitation uptake.

Impacts of Sanitation on Child Mortality and School Enrollment: A Country-Level Analysis

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Introduction

Sustainable access to water and sanitation for all is one of the ambitious goals of the Sustainable Development Goals (SDGs) declared by the United Nations (UN) in 2015. While there has been significant progress toward this goal in the past decade, a recent report by the UN (2020) reveals that billions of people across the globe still lack access to basic sanitation. More specifically, 4.2 billion people worldwide lack safely managed sanitation, including 2 billion who are without basic sanitation. Further, poor hygiene remains a serious concern. Handwashing, which is the cheapest, easiest, and most effective way of maintaining good hygiene and can potentially prevent the spread of the coronavirus disease (COVID-19), is still not accessible to 75% of the population in sub-Saharan Africa, 42% of the population in Central Asia and South Asia, and 23% of the population in Northern Africa and West Asia (UN 2020).

In terms of sanitation investments, over the years, governments, multilateral organizations, and private actors have invested substantial amounts to promote sanitation, especially in developing countries. The Asian Development Bank (ADB), for instance, has completed 63 sanitation projects across its various developing member countries and has invested $681.14 million in the People's Republic of China, $153.70 million in India, $56.64 million in Indonesia, $37.09 million in Fiji, and $34.96 million in Viet Nam (ADB 2018). Local governments across countries have collaborated with various stakeholders to deliver programs on sanitation, including community-led total sanitation campaigns, information dissemination initiatives, financing schemes (subsidies and cross-subsidies to households), incentives to villages, and construction of sanitation facilities (Revilla, et al. 2021). This brief aims to assess whether these local- and national-level investments trickled down to improvements in human capital, particularly to decreases in child mortality, increases in school enrollment, and increases in gender parity in schooling. Based on the findings, it pinpoints policy recommendations to advance SDG 6 and other related SDGs.

This study contributes to the limited empirical literature on sanitation by estimating the causal effect of sanitation on development outcomes using country-level data from the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene[1] and other sources. It employs an instrumental variable two-stage least squares (IV 2SLS) approach to address the endogeneity of sanitation.

The remaining sections of this policy brief explore the previous literature, present the empirical strategy and data, discuss the results, and finally, provide the conclusion and policy recommendations.

Sanitation, Health, and Education

In this section, we review the previous empirical literature on sanitation, focusing on its impact on human development outcomes, i.e., health, education, and gender parity in schooling.

Kumar and Vollmer (2012) evaluate the impact of sanitation on childhood diarrhea in rural India. Using propensity score matching, they find that access to improved sanitation reduces the risk of contracting diarrhea by 2.2 percentage points with considerable heterogeneity in their results. Similarly, Mallick, Mandal, and Chouhan (2020) verify the impact of sanitation and clean drinking water on the prevalence of diarrhea among children under five in India. They also find that improved sanitation reduces diarrhea prevalence among these children. Likewise, wider latrine coverage and sanitation campaigns lead to an increase in height (Augsburg and Rodríguez–Lesmes 2018) and higher mid-upper-arm circumference and weight among children in India (Dickinson, et al. 2015). Stewart et al. (2018) assess the effects of water quality, sanitation, handwashing, and nutritional interventions on child development in rural Kenya using a cluster-randomized controlled trial. Their results reveal that handwashing and combined water, sanitation, handwashing, and nutrition interventions lead to improvements in child physical development after 1 year. However, there were no differences found between the control and treatment groups after 2 years.

In terms of the impacts on educational outcomes, specifically on schooling and learning, most evidence shows the favorable impacts of sanitation. Adukia (2017) explores whether the absence of school sanitation infrastructure impedes educational attainment, particularly among pubescent-age girls in India. Using a difference-in-difference approach, the findings show that school latrine construction substantially increases the enrollment of pubescent-age girls. This is especially true when sex-specific latrines are provided, indicating that privacy and safety are important for pubescent-age girls and that sex-specific latrines can reduce gender disparities in schooling. Another milestone study in this field is a cluster-randomized trial evaluating the impact of school water, sanitation, and hygiene (WASH) improvements on enrollment and gender parity in enrollment by Garn et al. (2013). They find that comprehensive WASH programs in schools in Nyanza, Kenya, increase enrollment and gender parity. In a study conducted in Malawi, Mchenga, Phuma–Ngaiyaye, and Kasulo (2020) note that sanitation facilities in primary and secondary schools contribute to proper menstrual hygiene management among girls. Further, some empirical studies investigate the relationship between sanitation and cognitive skills. Spears and Lamba (2016) mention that 6-year-old children who were exposed to India's Total Sanitation Campaign in their first year of life are more likely to recognize letters and simple numbers. Orgill–Meyer and Pattanayak (2020) point out the positive correlation between village latrine coverage and long-term test scores in rural Odisha, India.[2] They emphasize that the effect on test scores is significantly larger among girls than boys. Dearden et al. (2017) report that access to improved water and toilets has positive effects on children's language skills. Meanwhile, Sclar et al. (2017) systematically review the effects of sanitation on cognitive development and school absence. They find that while sanitation supports cognitive development, it has inconclusive effects on school absence.

To contribute further to this research, this study reassesses the impact of sanitation on child mortality, enrollment, and gender equity in enrollment on a macro scale. It utilizes cross-sectional country-level data, instead of individual-level data, and employs an instrumental variable method to establish causality between sanitation and the various outcomes of interest.

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1 Accessed from washdata.org on 15 March 2021.
2 In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Empirical Strategy and Data

Empirical Strategy

To address our goals, we follow three steps. First, we test the endogeneity of sanitation as an explanatory variable. Endogeneity may exist due to reverse causality. For instance, higher child mortality (our dependent variable) may lead to an increase in sanitation uptake (our independent variable). This reversal of effects confounds our results, particularly in an ordinary least squares (OLS) regression. We conduct a test for endogeneity using the Durbin–Wu–Hausman test. Second, after verifying the endogeneity of sanitation, we address the issue by employing IV 2SLS. The first stage of IV 2SLS tests the correlation condition, wherein a selected instrumental variable should be highly correlated with the endogenous sanitation variable. Likewise, the instrumental variable must satisfy the exclusion restriction, which means that it should not be correlated with the outcomes of interest (child mortality, enrollment, and gender parity). Several diagnostics can be conducted to verify the instrumental variable's validity. Third, the predicted values of sanitation from the first stage are used to run a regression in the second stage.

We use the following models to estimate the impact of sanitation in the second stage. Equation 1 shows our model for effects on child mortality. The variable *childmortality* refers to the mortality rate for children under 5 years old per 1,000 live births, while *sanitation* represents the percentage of people using at least basic sanitation services, that is, improved sanitation facilities that are not shared with other households. Improved sanitation facilities include flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, compositing toilets, or pit latrines with slabs. We add *literacyrate* (the percentage of people aged 15 or above who can both read and write and understand a simple statement) and *healthexpenditure* (total expenditure on health as percentage of gross domestic product) as control variables. β_1 represents the causal impact of sanitation on child mortality.

$$childmortality = \beta_0 + \beta_1 sanitation + \beta_2 literacyrate + \beta_3 healthexpenditure + \epsilon_1 \qquad (1)$$

Equations 2, 3, and 4 estimate the impact of sanitation on gross enrollment rates at the primary, secondary, and tertiary levels. We define the variables as follows. *GERprim/ GERsec/ GERter* refer to the number of students enrolled in primary/secondary/tertiary education, regardless of age, expressed as a percentage of the

official school-age population corresponding to the same level of education; *ruralpop* stands for the percentage of the population living in rural areas; and *developmentassistance* is the amount of water- and sanitation-related official development assistance that is part of the government's spending plan. The coefficients of interest are β_5, β_9, and β_{12}, which represent the causal impact of sanitation access on gross enrollment rates.

$$GERprim = \beta_4 + \beta_5 sanitation + \beta_6 ruralpop + \beta_7 developmentassistance + \epsilon_2 \qquad (2)$$

$$GERsec = \beta_8 + \beta_9 sanitation + \beta_{10} ruralpop + \epsilon_3 \qquad (3)$$

$$GERter = \beta_{11} + \beta_{12} sanitation + \beta_{13} ruralpop + \epsilon_4 \qquad (4)$$

Moreover, Equations 5, 6, and 7 assess the impact of sanitation on gender parity in enrollment. *GPIprim/ GPIsec/ GPIter* stand for the Gender Parity Index for the gross enrollment rate in primary/secondary/tertiary education, which is the ratio of girls to boys enrolled in primary/secondary/tertiary public and private schools. The models also control for *ruralpop*. The coefficients of interest are β_{15}, β_{19}, and β_{22}, which reflect the causality between household sanitation and gender parity in schooling. Finally, ϵ_n in Equations 1–7 represents the error term for the second stage.

$$GPIprim = \beta_{14} + \beta_{15} sanitation + \beta_{16} ruralpop + \beta_{17} developmentassistance + \epsilon_5 \qquad (5)$$

$$GPIsec = \beta_{18} + \beta_{19} sanitation + \beta_{20} ruralpop + \epsilon_6 \qquad (6)$$

$$GPIter = \beta_{21} + \beta_{22} sanitation + \beta_{23} ruralpop + \epsilon_7 \qquad (7)$$

We select two instrumental variables for our IV 2SLS regressions. First, we use *access to electricity* for sanitation in the child mortality function. This satisfies the correlation condition as more access to electricity may also improve delivery of sanitation services (i.e., through more efficient water supply access and the construction of facilities). Likewise, electricity and sanitation access may be highly correlated since they both represent the level of infrastructure investment that a community receives. This instrumental variable may also satisfy the exclusion restriction criteria since electricity access is not expected to be highly or directly correlated with child mortality. Such infrastructure may pass through other channels first before it can affect child health. Second, in the case of enrollment and gender parity, we utilize the *share of the population with an improved water source*. An improved drinking water source includes "piped water on premises and other improved drinking water

sources (i.e., public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection)." This instrumental variable also satisfies the correlation and exclusion restriction criteria since it contributes to better sanitation in households and may not directly affect enrollment or gender parity in schooling.

Data

For Equations 1–7, we utilize cross-section data of countries in 2015, which is the year with the largest sample of available data across variables. In total, we have a sample of 140 countries for the impact on *childmortality*, 84 countries for *GERprim* and *GPIprim*, 109 countries for *GERsec* and *GPIsec*, and 103 countries for *GERter* and *GPIter*. Note that since most of these countries are low-income and middle-income, we can assess the impact of sanitation in mostly developing regions.

Data on child mortality and health expenditure are gathered from the UN Inter-agency Group for Child Mortality Estimation and the World Health Organization (WHO) health statistics.[3] The data on sanitation are collected from the WHO/UNICEF JMP for Water Supply, Sanitation and Hygiene.[4] Moreover, enrollment, gender parity, and literacy rate data are derived from the UNESCO (UN Educational, Scientific and Cultural Organization) Institute for Statistics.[5] Data on development assistance, rural population, and access to electricity are extracted from the World Bank, Sustainable Energy for All (SE4ALL) database based on the SE4ALL Global Tracking Framework.[6] Finally, the data on share of population having improved water source are taken from Our World in Data database.[7]

Results

Based on the Durbin–Wu–Hausman test, *sanitation* is endogenous in the equations for *childmortality*, *GPIpri*, *GERsec*, *GPIsec*, and *GPIter*.[8] The p-values of the Durbin score and Wu-Hausman F-statistic are less than 0.05 in these cases. Hence, we reject the null hypothesis that *sanitation* is exogenous. To deal with

the endogeneity issue, we conduct IV 2SLS regressions using valid instruments. The under identification and weak identification tests in Tables 1 and 2 show that our selected instrumental variables (*access to electricity* and *improved water source*) are valid. Importantly, Table 1 presents the OLS and IV 2SLS[8] results on the impact of sanitation on under-5 child mortality. We find that a 1 percentage point increase in the share of population with access to at least basic sanitation decreases the under-5 child mortality rate by 0.84 percentage points. The result is highly significant at the 1% level. Indeed, the causal impacts found using micro-level empirical data are also reflected in the macro-level data. Sanitation is a worthy investment if governments aim to support early childhood health. A clean and safe environment decreases the chance of contracting water-borne diseases that often attack younger children. This further indicates that achieving progress in SDG 6 translates to progress in SDG 3 (good health and well-being).

Table 1: Effect of Basic Sanitation on Child Mortality, by Country, 2015

Dependent Variable	Child Mortality Rate	
Specification	OLS	IV 2SLS
Basic sanitation	−0.543***	−0.838***
	(0.066)	(0.097)
Literacy rate	−0.617***	−0.255 ***
	(0.103)	(0.580)
Health expenditure	−0.063	0.238
	(0.547)	(0.580)
Observations	140	140
R-squared	0.786	0.758
Underidentification test		73.758
Weak identification test		151.431

IV 2SLS = instrumental variable two-stage least squares, OLS = ordinary least squares.

Note: The instrumental variable used in the IV 2SLS is *access to electricity*. The underidentification test is based on the Kleibergen–Paap statistic, which confirms that the equation is identified and the instrument is relevant or correlated with the endogenous regressor. The weak identification test, measured by the Cragg–Donald Wald F-statistic, tests the possibility of "weak identification" and the strength of the correlation between the endogenous regressor and instrument. Standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels.

Source: Authors' calculations.

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3 Accessed from www.childmortality.org and https://apps.who.int/iris/handle/10665/170250 on 15 March 2021.
4 Accessed from https://washdata.org on 15 March 2021.
5 Accessed from http://uis.unesco.org/ on 15 March 2021.
6 Accessed from https://datacatalog.worldbank.org/dataset/sustainable-energy-all on 15 March 2021.
7 Accessed from https://ourworldindata.org/water-access on 15 March 2021.
8 For *GERpri* and *GERter*, we found no evidence to reject exogeneity.
9 We conduct both OLS and IV 2SLS estimations to check the robustness of our results across specifications. Interestingly, the sign and significance of *sanitation* in both runs are similar.

Table 2: Effect of Basic Sanitation on Gross Enrollment Rate and Gender Parity Index, by Country, 2015

Dependent Variable	Primary Gross Enrollment Rate		Primary Gender Parity Index	
Specification	**OLS**	**IV 2SLS**	**OLS**	**IV 2SLS**
Basic sanitation	0.011	0.0272	0.000806***	0.00155***
	(0.061)	(0.084)	(0.00028)	(0.00054)
Rural area	0.132	0.143	−0.0001487	0.00038
	(0.089)	(0.0968)	(0.00041)	(0.00039)
Development assistance	−0.010	-0.0094	0.000144*	0.000178**
	(0.018)	(0.018)	(0.00008)	(0.00009)
Observations	84	84	84	84
R-squared	0.031	0.012	0.13900	0.06300
Underidentification test		67.107		26.576
Weak identification test		135.508		84.059
Dependent Variable	**Secondary Gross Enrollment Rate**		**Secondary Gender Parity Index**	
Specification	**OLS**	**IV 2SLS**	**OLS**	**IV 2SLS**
Basic sanitation	0.765***	0.919***	0.00233***	0.00342***
	(0.067)	(0.071)	−0.000525	−0.000901
Rural area	−0.291***	(0.158)	0.00027	0.00122*
	(0.102)	(0.098)	(0.00049)	(0.00064)
Observations	109	109	109	109
R-squared	0.755	0.743	0.26	0.224
Underidentification test		27.7660		27.7660
Weak identification test		143.271		143.271
Dependent Variable	**Tertiary Gross Enrollment Rate**		**Tertiary Gender Parity Index**	
Specification	**OLS**	**IV 2SLS**	**OLS**	**IV 2SLS**
Basic sanitation	0.516***	0.609***	0.00715***	0.00946***
	(0.088)	(0.122)	(0.001)	(0.001)
Rural area	−0.385***	−0.307**	−0.00210*	(0.000)
	(0.110)	(0.150)	(0.001)	(0.002)
Observations	103	103	103	103
R-squared	0.572	0.567	0.589	0.563
Underidentification test		21.983		21.983
Weak identification test		95.029		95.029

IV 2SLS = instrumental variable two-stage least squares, OLS = ordinary least squares.

Note: The instrumental variable used in the IV 2SLS is the *share of the population with an improved water source*. The underidentification test is based on the Kleibergen–Paap statistic, which confirms that the equation is identified and the instrument is relevant or correlated with the endogenous regressor. The weak identification test, measured by the Cragg–Donald Wald F-statistic, tests the possibility of "weak identification" and the strength of the correlation between the endogenous regressor and instrument. Standard errors in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels.

Source: Authors' calculations.

In terms of schooling, Table 2 provides suggestive evidence of positive causal impacts of sanitation on gross enrollment rates and the gender parity index at the primary, secondary, and tertiary education levels. The results are consistent across the OLS and IV 2SLS estimations. We note that the impact on the primary gross enrollment rate, though positive, is statistically insignificant. The positive effect of sanitation on enrollment is more prominent in secondary and tertiary education. These findings may indicate that, first, the health improvements of young children due to sanitation have yet to be translated to higher primary school enrollment. Other policies to drive up enrollment of primary school-aged children must be put in place (i.e., feeding programs, free textbooks, allowances, etc.). Second, sanitation is evidently more important among adolescents, compared with younger children, for hygiene reasons. As children grow older, they learn to value cleanliness and, thus, rely more on improved sanitation facilities. This is especially true among girls who enter pubescent age. Hence, SDG 6 plays an important role in driving progress in SDG 4 (access to quality education) and SDG 5 (gender equality).

Moreover, Table 2 demonstrates the effect of sanitation on gender parity in enrollment. We find highly significant positive impacts in our OLS and IV 2SLS estimations. Clearly, the share of girl enrollees increases at a higher rate as sanitation infrastructure improves. Previous literature shows that girls depend more on sanitation facilities, especially when they enter pubescence, for privacy, safety, and proper menstrual hygiene management. We expect the impact on girls' enrollment to increase if schools, and not only households, provide more toilet and washing facilities. Notably, these public toilets should be well-maintained.

Conclusion and Policy Recommendations

Conclusion

In this paper, we assessed the impact of sanitation on child mortality, enrollment, and gender parity in enrollment using an OLS and IV 2SLS approach. We utilized publicly available data of around 100 countries in each of our regressions. Conclusively, our macro-level findings echo the findings from previous micro-level empirical research. We establish positive causal relations between sanitation investments and human capital improvements on a macro scale.

Policy Recommendations

Given these findings, we highlight some policy recommendations. First, sanitation funds should be clearly allocated toward building and maintaining accessible toilets in poor areas and slums where many children are exposed to unhealthy environments. Early childhood health, one of the top advocacies of the WHO, is clearly linked to sanitation, and so sanitation projects of local governments and national health units, especially in disadvantaged areas, should be well-aligned.

Second, the importance of sanitation on education cannot be overemphasized. On the one hand, households and schools should demand for better sanitation infrastructure from their local governments, which can be done through campaigns for higher funding and technical support. Given the results of this study, school officials should advocate for better sanitation facilities for their students. On the other hand, local governments should ensure that toilet facilities are constructed, maintained, and utilized fully at home and in schools. Indeed, coordination among various stakeholders (from the demand and supply side) is vital in expanding sanitation delivery and improving schooling outcomes.

Third, based on our findings, improved sanitation causally increases the enrollment of girls at the primary, secondary, and tertiary levels. This means that girls tend to benefit more from sanitation than boys. Thus, programs should be specifically designed to cater to girls' needs. A good example for this is providing sex-specific toilets rather than unisex toilets and including clean washing facilities and sanitary items to support menstrual hygiene.

Fourth, aside from constructing toilets in the community, a critical aspect of achieving inclusive sanitation is ensuring that these toilets are being utilized and

We establish positive causal relations between sanitation investments and human capital improvements on a macro scale.

Monitoring, collecting, and integrating sanitation data at the national and local levels remain crucial.

maintained by the targeted users themselves. Given some structural constraints that hinder the use of sanitation facilities (i.e., culture, norms, religion, caste system, etc.), we reiterate the importance of behavioral change campaigns to influence toilet usage. These can be done through strategic information dissemination (using flyers, posters, text messages, advertisements on social media, etc.), regular provision of guidelines on maintaining toilet facilities, and personal or online consultations between local authorities and households. Similarly, in the case of poor households, providing financial support (i.e., microfinance, loans, and subsidies) will also help improve sanitation access.

Fifth, from a research standpoint, there is more work to be done. Although our results suggest initial progress in sanitation, health, and education, the latest Asia and the Pacific SDG report[9] indicates the lack of sufficient indicators to accurately measure progress in SDG 6. This means that monitoring, collecting, and integrating sanitation data at the national and local levels remain crucial. Panel data will be especially useful

in strengthening evidence on the long-term effects of sanitation (i.e., on employment outcomes and the income of children exposed to the intervention).

Finally, in future studies, we recommend looking into other aspects of sanitation and gender (i.e., the role of women in sanitation delivery and the impacts on women's labor force participation and marriage decisions) once reliable data become available. Likewise, another area of interest is the macro-level impact of sanitation on children's learning outcomes, which can be conducted using country-level data on international standardized exams (i.e., the Programme for International Student Assessment or the Trends in International Mathematics and Science Study).

To sum up, this policy brief reiterates the importance of sanitation in advancing human capital. It delivers lessons and recommendations that can potentially contribute to policy making and research on SDG 6 and other related SDGs.

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10 See https://data.unescap.org/publications/sdg-progress-report-2020 for details.

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