Research Paper

Interaction of village and school latrines on educational outcomes in India

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ABSTRACT

Research has shown that improved sanitation environments can lead to better educational outcomes. Similarly, there is some evidence that school latrines may also improve school enrollment and attendance, particularly for girls. This paper explores the interaction effect of village-level latrine coverage and school latrines on child educational outcomes. The overall improved sanitation conditions from higher latrine coverage and the presence of school latrines might produce an additive effect and improve educational outcomes even further. Using multiple years of data from the Annual Status of Education Report (ASER) in India, this paper shows that there is no evidence of an additive effect. However, across multiple models, village-level latrine coverage is associated with lower school dropout rates and higher test scores, particularly among girls. School latrines do not appear to have a strong positive association with educational outcomes.

Key words | education, gender, India, sanitation

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INTRODUCTION

As of 2018, 40% of the rural Indian population practiced open defecation (UNICEF 2018). Open defecation has large health, time, and dignity costs (Checkley *et al.* 2004; Cutler & Miller 2005; Wolf *et al.* 2014; Caruso *et al.* 2015; Dickinson *et al.* 2015; Augsburg & Rodríguez-Lesmes 2018). Recent research has also shown that improved sanitation increases human capital by improving education outcomes (Ortiz-Correa *et al.* 2016; Spears & Lamba 2016; Adukia 2017; Orgill-Meyer & Pattanayak 2020). Accounting for these improved human capital benefits is important to consider in sanitation interventions.

In a systematic review by Sclar *et al.* (2017), the authors propose a causal pathway for the effects of sanitation on educational outcomes, including attendance/absenteeism, enrollment, and test scores. In the review, both household/community sanitation and school sanitation are shown to have an effect on school absences. Access to improved sanitation at the household or community level has been shown to lower the risk of fecal exposure, which in turn lowers the rates of infection and illness. These lower rates of infection and illness both improve cognitive development and increase the ability to attend school. This increased ability to attend school may result in increased school enrollment if the health returns are substantial, decreased school absenteeism, and improved school performance as measured by test scores. Sclar *et al.* (2017) also theorize that access to improved school sanitation provides a more comfortable learning environment and thus increases the desire to attend school. In this paper, I investigate the interaction between community sanitation and school sanitation on a range of educational outcomes in India. Before discussing this interaction, I first provide an overview of the literatures investigating: (a) the link between household/community sanitation and educational outcomes and (b) the link between school sanitation and educational outcomes.

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Household/community sanitation and educational outcomes

There is a strong literature establishing the impact of improved sanitation environments on reductions in infection and illness in children (Wolf *et al.* 2014; Freeman *et al.* 2017). Recent research has highlighted the effect of reduced sanitation-related infections and illnesses on cognitive development. Pinkerton *et al.* (2016) show that diarrhea is a significant predictor of delayed cognitive development among a number of different measures. Cumulative fecal exposure contributes to environmental enteropathy, which inhibits the absorptive capacity of the gut even when otherwise asymptomatic (Petri Naylor & Haque 2014; Crane Jones & Berkley 2015; Mbuya & Humphrey 2016). Reductions in enteric infections contributing to environmental enteropathy are also correlated with improvements in cognitive development (Petri *et al.* 2008; Jiang *et al.* 2014; Watanabe & Petri Jr 2016; Kosek 2017).

Beyond the mechanism of infections contributing directly to cognitive development, a growing body of literature investigates the impact of household/community sanitation improvements on other educational outcomes. Reductions in illnesses and infections as a result of improved sanitation environments may increase the ability of children to attend school, which could in turn contribute to enhanced cognitive development (Sclar *et al.* 2017). Research investigating community-level sanitation improvements on school attendance provides mixed results. A piped sewer intervention in Yemen demonstrated no effect on school attendance (Klasen *et al.* 2012), whereas an improved drainage intervention in Pakistan was associated with significant improvements to school attendance particularly for girls (Rauniyar Orbeta & Sugiyarto 2011). Notably, both of these interventions were coupled with community-wide water supply improvements, making it difficult to disentangle the sanitation improvements on school outcomes. Ortiz-Correa *et al.* (2016) find that sewerage systems in Brazil increase the total years of schooling attained. Research investigating household-level sanitation rather than community-wide sanitation finds that household sanitation is significantly correlated with reduced school absences (Dreibelbis *et al.* 2013; Park *et al.* 2015) and improved school attendance (Battiston *et al.* 2013), though all of these studies are cross-sectional making causal claims difficult.

School sanitation and educational outcomes

School sanitation conditions also play a role in impacting educational outcomes. Access to latrines or toilets in school creates a more comfortable learning environment, thus enhancing the desire to attend school (Sclar *et al.* 2017). There is mixed empirical evidence on school sanitation and educational outcomes. Grant Lloyd & Mensch (2013) do not find that the presence of school latrines or latrine quality correlates with absenteeism in menstruating girls in Mali, and Caruso *et al.* (2014) find no impact of a latrine cleaning intervention on school absences in Kenya. School WASH intervention studies have been shown to decrease absenteeism (Freeman *et al.* 2011; Trinies *et al.* 2016), though it is difficult to assess the role of sanitation alone in these interventions. Dreibelbis *et al.* (2013) find that school latrine maintenance is correlated with reduced school absences for both boys and girls. Adukia (2017) and Garn *et al.* (2013) use school enrollment rather than absenteeism as their outcome of interest. Adukia (2017) finds that the presence of sex-specific latrines increased school enrollment and test scores of pubescent-age girls in India. One explanation for why school latrines may have an effect on school enrollment or attendance for pubescent-age girls is the additional privacy they offer to girls who are menstruating (Alam *et al.* 2017). Similarly, a school-based WASH intervention increased school enrollment particularly among girls in Kenya (Garn *et al.* 2013).

Interaction of community and school latrines on education outcomes

In this paper, I explore the interaction of the village sanitation environment and the school sanitation environment on educational outcomes in India. Most of the research to-date that explores the effect of improved sanitation on educational outcomes either uses sanitation improvements at the household/community level or school toilets/latrines as their variable of interest as discussed above and summarized in B1–B3 in Table 1. Only one paper investigates both school and household-level sanitation (Dreibelbis *et al.* 2013); however, they do not explore the interaction effect and rely on cross-sectional data. This paper adds to this existing literature by being the first to use a panel dataset

Table 1 | Predicted effects of the interaction of school and village latrines on education outcomes

	No school latrines	Presence of school latrines
Low village-level latrine coverage	B1: **Poor educational outcomes**	B2: More desirable learning environment → **Improved educational outcomes**
High village-level latrine coverage	B3: Decreased fecal exposure → decreased infection and illness → **Improved educational outcomes**	B4: **Hypothesized additive effect (>B2 + B3)**

Educational outcomes include: absenteeism/attendance, school enrollment, and test scores.

to investigate the interaction effect of village-level sanitation and school sanitation on educational outcomes. I use village-level sanitation rather than household sanitation because of the positive externalities that sanitation provides (Alderman Hentschel & Sabates 2003; Watson 2006; Fuller *et al.* 2016). Existing literature suggests that the primary mechanism through which sanitation improves educational outcomes is through reduced fecal exposure and thus reduced infections and illnesses (Pinkerton *et al.* 2016; Watanabe & Petri Jr 2016; Kosek 2017; Sclar *et al.* 2017). It is unlikely that reductions in fecal exposure from increased latrine adoption accrue to only the household that adopts the latrine. Using village-level sanitation rather than household sanitation accounts for the health externalities of an improved sanitation environment (Alderman Hentschel & Sabates 2003; Buttenheim 2008; Fuller *et al.* 2016; Geruso & Spears 2018).

As discussed above, there is a growing literature suggesting that both household/community sanitation and school sanitation are important predictors of educational outcomes as measured by attendance/absenteeism, school enrollment, and test scores, though some research shows weak or no effects. In this paper, the main hypothesis is that the interaction of improved village-level sanitation and school sanitation produces an additive effect on educational outcomes. In other words, does improved village-level sanitation and school sanitation produce educational outcomes over and above what one would observe with just improved village-level sanitation or school sanitation? I hypothesize that the more desirable learning conditions from school latrines combined with the reduced infection rates from village latrine coverage produce even greater educational returns (see Table 1). Using absenteeism as an example outcome, existing research shows that improved sanitation environments and school latrines are correlated with lower rates of absenteeism (Freeman *et al.* 2011; Rauniyar Orbeta & Sugiyarto 2011; Battiston *et al.* 2013; Dreibelbis *et al.* 2013; Park *et al.* 2015; Trinies *et al.* 2016). If a school latrine offers an additional incentive to attend school, the health conditions resulting from the improved sanitation environment may reduce absenteeism even further. The educational outcome variables that I use to test this hypothesis are school dropout rates and math test scores. I explain this choice of variables further in the following section.

There are two alternatives to the additive hypothesis. First, there may be no interaction effect – that is school latrines, and village sanitation environments produce improved educational outcomes independently and thus there is no complementary effect. Second, there may be a substitution effect, where, in the presence of both school latrines and improved village sanitation environments, educational outcomes actually worsen. The substitution effect would occur if the increased likelihood of having a latrine at home weakens the additional incentive provided by school latrines to enroll in or attend school. In this study, I make use of a large national Indian dataset to test the proposed additive effects shown in B4 in Table 1.

METHODS

Data overview

To investigate this research question, I use data from India's Annual Status of Education Report (ASER) survey. ASER is an annual survey, which collects data on childhood educational attainment in rural India. Specifically, ASER measures educational outcomes (school enrollment and educational attainment tests) for approximately 600,000 children ages 3–16. ASER surveys 30 villages per rural district and interviews 20 households per village in each year of data collection. Additionally, ASER collects data on one government school per village, gathering data on teaching indicators and school infrastructure (including school latrine status). Each year ASER randomly replaces 10 villages from each district. Pooling different years of ASER data results in a repeated cross-section at the household level and an unbalanced panel at the village and school level since most villages and schools are observed for multiple years.

Statistical model

The model used to test the effect of the interaction of school latrines and village latrine coverage on education outcomes is estimated with the ordinary least squares model shown below.

$$\begin{aligned}\text{Outcome}_{ijt} = {} & \beta_0 + \beta_1 \text{Vil\_Latrine}_{jt} + \beta_2 \text{School\_Latrine}_{jt} \\ & + \beta_3 \text{Female}_i + \beta_4 \text{Vil\_Latrine}_{jt} \times \text{School\_Latrine}_{jt} \\ & + \beta_5 \text{Vil\_Latrine}_{jt} \times \text{Female}_i \\ & + \beta_6 \text{School\_Latrine}_{jt} \times \text{Female}_i \\ & + \beta_7 \text{Vil\_Latrine}_{jt} \times \text{School\_Latrine}_{jt} \times \text{Female}_i \\ & + \beta_8 \text{Age}_{ijt} + \gamma \text{HHchars}_i + \theta_j + \delta_{kt} + \varepsilon_{ijt}\end{aligned}$$

I use two measures of educational outcomes as the dependent variables in the above model: (1) math test scores and (2) a binary variable for whether the child has dropped out of school. ASER does not measure reported school attendance or absenteeism – the two measures often used in the literature on WASH and educational outcomes (Rauniyar Orbeta & Sugiyarto 2011; Battiston *et al.* 2013; Dreibelbis *et al.* 2013; Caruso *et al.* 2015; Park *et al.* 2015; Trinies *et al.* 2016). I use math test scores as a proxy for attendance and absenteeism with the assumption that children that attend school more frequently will score higher on these tests. The score, as measured by ASER, ranges from 0 to 4, with 0 meaning that the child was unable to complete any of the questions accurately on the test, 1 indicating that the child correctly identified a number between 1 and 9, 2 representing that the child correctly identified a number between 10 and 99, 3 representing that the child correctly solved a subtraction problem, and 4 indicating that the child correctly solved a division problem. Math test scores have been used as a proxy for impact of sanitation on educational attainment when absenteeism and attendance metrics are unavailable (Spears & Lamba 2016; Adukia 2017). The school dropout indicator acts as a proxy for school enrollment since children who have dropped out of school will not be enrolled. While there is some evidence of the impact of school latrines on female enrollment (Garn *et al.* 2013; Adukia 2017), there is no literature that studies the impact of community sanitation environments on school enrollment. Ortiz-correa *et al.* (2016) do find that community-wide sanitation improvements increase overall years of completed schooling. I use a linear probability model for this outcome variable, though results are similar when using probit and logistic regressions.

Vil_Latrine_{jt} measures the proportion of households in village j in year t that have latrines. Since ASER randomly samples 20 households from each village included in the survey, this variable should approximate actual village-level latrine coverage. $\text{School\_Latrine}_{jt}$ is an indicator variable with one representing whether there is a usable girls' toilet or latrine present at the school in village j at time t. Since the literature on school latrines and educational outcomes has found that separate-sex latrines are important to create enrollment or attendance incentives, particularly for girls (Garn *et al.* 2013; Adukia 2017), usable girls' toilets or latrines are the relevant variable for this analysis. Female_i is an indicator variable taking the value of one if the child is a female and zero if the child is a male. Interactions between these three independent variables are represented by β_4, β_5, β_6, and β_7. The coefficients of interest are β_4 which measures the effect of the interaction of school latrines and village latrine coverage on the outcome variables, and β_7 which measures whether this interaction effect differs by gender.

Using the model from Equation (1), I include the full set of school-age children in the ASER data (ages 6–16). Included as controls are the child's age, Age_{ijt}, and a vector of household characteristics, HHchars_i, specifically whether the child's mother attended secondary school (Black Devereux & Salvanes 2005; Carneiro Meghir & Parey 2013) and an index of household wealth discussed below. θ_j represents village fixed-effects which control for time-invariant village characteristics and δ_{kt} represents state (k) by year fixed-effects which control for state-level time trends. The ability to include village fixed-effects is an important feature of ASER data, which allows for the control of many village-level confounding factors that may also affect educational attainment.

The ASER household survey includes a series of asset questions measuring household wealth. Rather than including multiple asset ownership indicator variables as a control, I used principal component analysis (PCA) to create an asset index for each household. The assets included in each index are: household latrines or toilets, electricity connection, televisions, and mobile phones. Using a PCA-created asset index is more appropriate than including separate asset variables when assets are correlated, which they are in the ASER data (Vyas & Kumaranayake 2006). Controlling for household sanitation is important to isolate the main effect of village-wide sanitation (Alderman Hentschel & Sabates 2003; Fuller *et al.* 2016); however, we also conduct a sensitivity analysis omitting household sanitation from the asset index and do not find significant differences in our main result (see Supplementary Tables 1A and 2A).

Data overview

I use annual ASER data from 2012, 2013, 2014, and 2016 (ASER data were not collected in 2015); I do not use earlier rounds of ASER data because information on school latrines was not collected prior to 2009 and the measurement for school dropout rates is inconsistent prior to 2012. As a result, I focus on the time period 2012–2016 in my analysis. For the math score outcome, I drop 2012 in the analysis since the metrics that ASER used to measure math scores changed in 2013. I drop any child observations in villages where data on usable female latrines in schools were missing, leaving a total sample size of 2,774,585 observations. Mother's education was missing for certain households, so the total sample size drops to 2,597,011 observations when including those control variables.

As shown in Table 2, both village-level latrine coverage and the percentage of schools with usable girls' toilets/latrines have increased dramatically over time between 2012 and 2016. These trends are also reflected in Figure 1 (which also shows pre-trends starting in 2009). The school dropout rate, on the other hand, does not appear to have changed over time. While the dropout rate is low (3.4% in 2016), ASER only measures if a student is officially not enrolled in school, and thus, this dropout rate does not capture low or no attendance among enrolled students.

Table 2 | Summary statistics over time

Variable	% in 2012 ($n = 392{,}440$)	% in 2016 ($n = 400{,}954$)
Village latrine coverage	40.3	53.5
Schools with usable girls' toilets/latrines	47.2	60.4
Children (ages 6 and above) having dropped out of school	3.4	3.4
Child is female	47.3	48.4
Mother attended secondary school	50.2	54.4
Household has electricity connection	75.6	82.5
Household has TV	48.8	54.2
Household has mobile phone	67.4	80.2

RESULTS AND DISCUSSION

Table 3 contains the main results for the school dropout outcome variable from the different models of Equation (1) outlined in the previous section. In each of the models, village latrine coverage is associated with a lower school dropout rate. According to Model 1, moving from no village latrine coverage to full coverage is associated with a 3.3% school dropout rate. The interaction between *Village latrine coverage* and *Female* also indicates that this effect is stronger for female children. This finding is consistent with other literature, suggesting that educational impacts of latrine coverage are more concentrated among female children (Garn *et al.* 2013; Adukia 2017; Orgill-Meyer & Pattanayak 2020).

Having a usable girls' latrine in the school is only associated with a statistically significant reduction in school dropout rates in two models (columns 2 and 4). Moreover, the effect does not appear to differ between female and male children. This finding suggests that overall village latrine coverage matters more for improving school enrollment than the presence of school latrines. The main result, the additive effect of village latrine coverage and school latrines, represented by the interaction *Village*

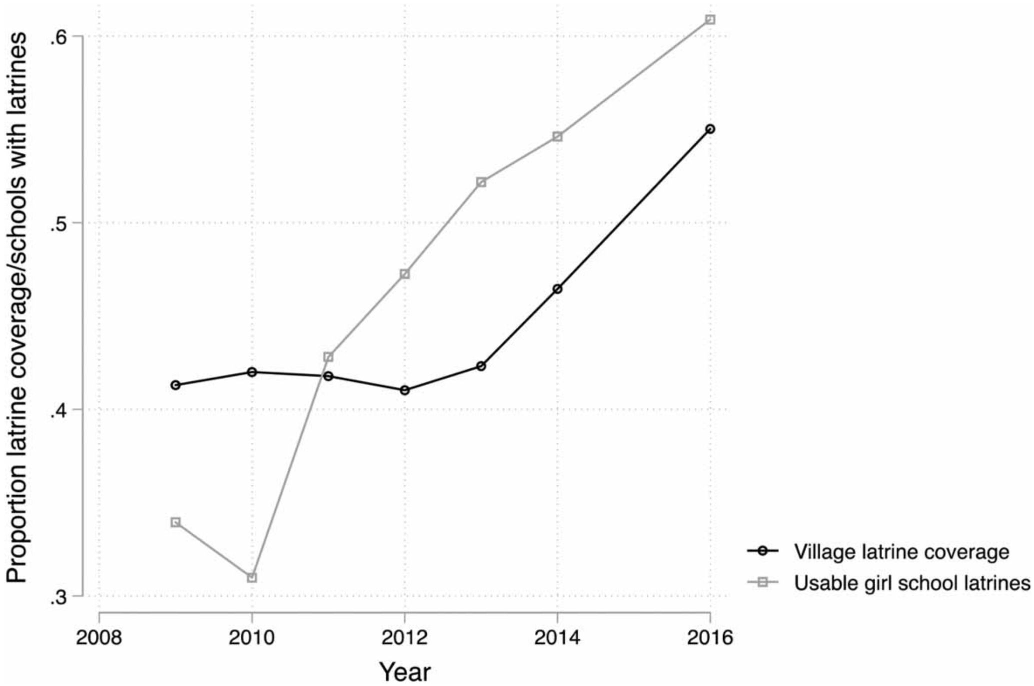

Figure 1 | Trends in latrine coverage (2009–2016).

Table 3 | Effect of latrine coverage and school latrines on school dropout rates

	(1)	(2)	(3)	(4)
Village latrine coverage	−0.033*** (0.001)	−0.044*** (0.004)	−0.010*** (0.004)	−0.009** (0.004)
School latrine	0.000 (0.001)	−0.006* (0.003)	−0.001 (0.003)	−0.005* (0.003)
Female	0.018*** (0.002)	0.010*** (0.002)	0.010*** (0.002)	0.011*** (0.002)
Village latrine coverage × female	−0.014*** (0.002)	−0.005** (0.002)	−0.004** (0.002)	−0.005** (0.002)
School latrine × female	−0.004 (0.003)	−0.000 (0.003)	−0.000 (0.003)	−0.001 (0.003)
Village latrine coverage × school latrine	−0.005*** (0.001)	0.003 (0.006)	−0.000 (0.005)	0.006 (0.005)
Village latrine coverage × school latrine × female	0.004 (0.003)	0.001 (0.003)	0.001 (0.003)	0.001 (0.003)
Child age	0.014*** (0.000)	0.014*** (0.000)	0.013*** (0.000)	0.013*** (0.000)
Mother attended secondary school			−0.021*** (0.000)	−0.021*** (0.000)
Household asset index			−0.014*** (0.000)	−0.014*** (0.000)
Constant	−0.096*** (0.001)	−0.093*** (0.002)	−0.099*** (0.002)	−0.095*** (0.010)
Observations	1,549,430	1,549,430	1,448,859	1,448,859
R^2	0.052	0.127	0.135	0.135
Village FE	No	Yes	Yes	Yes
State × year FE	No	No	No	Yes

Robust standard errors in parentheses; standard errors clustered at the village level. School latrine is defined as having a usable female latrine in the school. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Latrine Coverage × *School Latrines*, is negative and statistically significant in the base model (column 1). However, the coefficient does not have statistical significance when including village fixed-effects and other controls (columns 2–4), suggesting no evidence of an additive effect. There are also no differences in this interaction by gender.

Conducting the same analysis for each state in India reveals positive additive effects for only one Indian state: Kerala. This lack of additive effect at the state level further suggests that village latrine coverage and school latrines have independent channels of producing educational benefits. When looking at just the village latrine coverage effects on school dropout rate, there is a lot of heterogeneity at the state level as depicted in Table 4. This table contains the coefficients on village latrine coverage for each state. Most of the literature on village/household sanitation has used absenteeism and attendance as the dependent variables (Rauniyar Orbeta & Sugiyarto 2011; Battiston *et al.* 2013; Dreibelbis *et al.* 2013; Park *et al.* 2015). This finding is the first that suggests that village-level latrine coverage also can have an impact on school dropout rates. For the most part, the larger effect sizes are concentrated in the relatively wealthier states (with some exceptions – Bihar has a small but significant effect size), suggesting a possible threshold effect.

Table 5 depicts the same models with math scores as the dependent variable. Recall that math scores are being used as a proxy for attendance/absenteeism which is not captured in the ASER data. In the base model (column 1), both village latrine coverage and school latrines are associated with higher math scores, though these coefficients lose significance when including fixed-effects and other controls. Similar to the school dropout outcome, the effects of having higher village latrine coverage on math scores are higher among female children (consistent across all four models). However, there are no differential impacts of having school latrines by gender. Finally, there does not appear to be a statistically significant effect on the interaction of village latrine coverage and school latrines; nor do these coefficients differ by gender.

Taken together, there does not appear to be strong evidence of either an additive effect of village-level latrine coverage and school latrine on educational outcomes for either girls or boys. This lack of significance in the interactions between school and village latrines suggests that the channels through which village latrine coverage and school latrines affect educational outcomes are independent. While there does not appear to be support for an additive effect among school latrines and village latrine coverage, village-level latrine coverage does appear to consistently be associated with improved educational outcomes – reduced dropout rates and higher math scores – particularly among female children. This finding is significant when considering the economic gains that female education produces (Knowles *et al.* 2002); an important policy lever to achieving such gains could be to improve the overall sanitation environment.

Table 4 | Village-Level Latrine Coverage Effects on School Drop Out Rates by State

State	Coefficient	(Std Error)
Andhra Pradesh	-0.018**	(0.007)
Arunachal Pradesh	-0.006	(0.008)
Assam	0.010*	(0.005)
Bihar	-0.008*	(0.004)
Chhattisgarh	0.014*	(0.008)
Dadra & Nagar Haveli	-0.044	(0.035)
Daman & Diu	-0.009	(0.011)
Goa	-0.007	(0.007)
Gujarat	-0.010	(0.008)
Haryana	-0.027**	(0.011)
Himachal Pradesh	0.013	(0.011)
Jammu and Kashmir	-0.010**	(0.005)
Jharkhand	-0.001	(0.008)
Karnataka	-0.017***	(0.004)
Kerala	-0.134	(0.088)
Madhya Pradesh	-0.001	(0.005)
Maharashtra	-0.016***	(0.004)
Manipur	-0.001	(0.009)
Meghalaya	-0.019*	(0.011)
Mizoram	-0.009	(0.008)
Nagaland	0.014	(0.010)
Odisha	-0.012	0.008)
Pondicherry	0.020	(0.017)
Punjab	-0.004	(0.011)
Rajasthan	-0.019***	(0.007)
Sikkim	-0.052	(0.069)
Tamil Nadu	-0.006*	(0.003)
Telangana	-0.033	(0.023)
Tripura	-0.027	(0.022)
Uttar Pradesh	0.032***	(0.004)
Uttarakhand	0.014	(0.011)
West Bengal	0.011	(0.008)

*p < 0.01, **p < 0.05, ***p < 0.001

Table 5 | Effect of latrine coverage and school latrines on math scores

	(1)	(2)	(3)	(4)
Village latrine coverage	0.503*** (0.018)	0.377* (0.225)	0.243 (0.222)	−0.006 (0.269)
School latrine	0.061*** (0.013)	0.117 (0.184)	0.094 (0.176)	0.008 (0.176)
Female	−0.153*** (0.019)	−0.129*** (0.015)	−0.134*** (0.016)	−0.133*** (0.016)
Village latrine coverage × female	0.081*** (0.021)	0.058*** (0.016)	0.059*** (0.017)	0.059*** (0.017)
School latrine × female	−0.003 (0.028)	−0.012 (0.023)	−0.006 (0.024)	−0.006 (0.024)
Village latrine coverage × school latrine	0.009 (0.024)	0.023 (0.334)	−0.062 (0.321)	0.065 (0.319)
Village latrine coverage × school latrine × female	0.022 (0.030)	0.030 (0.024)	0.024 (0.025)	0.025 (0.025)
Child age	0.262*** (0.001)	0.259*** (0.001)	0.261*** (0.001)	0.261*** (0.001)
Mother attended secondary school			0.228*** (0.005)	0.227*** (0.005)
Household asset index			0.163*** (0.004)	0.162*** (0.004)
Constant	−0.716*** (0.012)	−0.678*** (0.101)	−0.641*** (0.098)	−0.425*** (0.126)
Observations	329,689	329,689	310,038	310,038
R^2	0.309	0.534	0.550	0.550
Village FE	No	Yes	Yes	Yes
State × year FE	No	No	No	Yes

Robust standard errors in parentheses; standard errors clustered at the village level. School latrine is defined as having a usable female latrine in the school. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

This study also faces a number of limitations. The changes in how ASER data measured school dropout and math scores restrict the number of years in the analysis. Further, the sampling strategy used by ASER produces an unbalanced panel at the village level and repeated cross-sections at the household level. As a result, the analysis can utilize village fixed-effects which control for time-invariant level factors but cannot use household fixed-effects. Controlling for maternal education and household wealth, two factors that contribute to child educational attainment, allows for the elimination of some omitted variable bias, but the analysis still does not produce fully causal results.

CONCLUSIONS

This paper uses a large dataset from India to analyze the effect of the interaction of village-level latrine coverage and school-based latrines on child educational outcomes. There does not appear to be strong evidence for an additive effect of village and school latrines on school dropout rates or math test scores. All models explored in this paper produce positive associations between village-level latrine coverage and educational outcomes – lower dropout rates and higher test scores, particularly for female children. The relationship between school latrines and educational outcomes appears weaker.

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SUPPLEMENTARY MATERIAL

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REFERENCES

Adukia, A. 2017 Sanitation and education. *American Economic Journal: Applied Economics* **9** (2), 23–59.

Alam, M. U., Luby, S. P., Halder, A. K., Islam, K., Opel, A., Shoab, A. K., Ghosh, P. K., Rahman, M., Mahon, T. & Unicomb, L. 2017 Menstrual hygiene management among Bangladeshi adolescent schoolgirls and risk factors affecting school absence: results from a cross-sectional survey. *BMJ Open* **7** (7), 1–10.

Alderman, H., Hentschel, J. & Sabates, R. 2003 With the help of one's neighbors: externalities in the production of nutrition in Peru. *Social Science & Medicine* **56**, 2019–2031.

Augsburg, B. & Rodríguez-Lesmes, P. A. 2018 Sanitation and child health in India. *World Development* **107**, 22–39.

Battiston, D., Cruces, G., Lopez-Calva, L. F., Luga, M. A. & Santos, M. E. 2013 Income and beyond: multidimensional poverty in six. *Social Indicators Research* **112** (2), 291–314.

Black, S. E., Devereux, P. J. & Salvanes, K. G. 2005 Why the apple doesn't fall far: understanding intergenerational transmission of human capital. *American Economic Review* **95** (1), 437–449.

Buttenheim, A. M. 2008 The sanitation environment in urban slums: implications for child health. *Population and Environment* **30** (1–2), 26–47.

Carneiro, P., Meghir, C. & Parey, M. 2013 Maternal education, home environments, and the development of children and adolescents. *Journal of the European Economic Association* **11**, 123–160.

Caruso, B. A., Freeman, M. C., Garn, J. V., Dreibelbis, R., Saboori, S., Muga, R. & Rheinegans, R. 2014 Assessing the impact of a school-based latrine cleaning and handwashing program on pupil absence in Nyanza Province, Kenya: a cluster-randomized trial. *Tropical Medicine and International Health* **19** (10), 1185–1197.

Caruso, B. A., Sevilimedu, V., Fung, I., Patkar, A. & Baker, K. K. 2015 Gender disparities in water, sanitation, and global health. *The Lancet* **386**, 650–651.

Checkley, W., Gilman, R. H., Black, R. E., Epstein, L. D., Cabrera, L., Sterling, C. R. & Moulton, L. H. 2004 Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. *Lancet* **363**, 112–118.

Crane, R. J., Jones, K. D. J. & Berkley, J. A. 2015 Environmental enteric dysfunction: an overview. *Food and Nutrition Bulletin* **36** (10), S76–S87.

Cutler, D. M. & Miller, G. 2005 The role of public health improvements in health advances: the twentieth-century United States. *Demography* **42** (1), 1–22.

Dickinson, K. L., Patil, S. R., Pattanayak, S. K., Poulous, C. & Yang, J. H. 2015 Nature's call: impacts of sanitation choices in Orissa, India. *Economic Development and Cultural Change* **64** (1), 1–29.

Dreibelbis, R., Greene, L. E., Freeman, M. C., Saboori, S., Chase, R. P. & Rheingans, R. 2013 Water, sanitation, and primary school attendance: a multi-level assessment of determinants of household-reported absence in Kenya. *International Journal of Educational Development* **33** (5), 457–465.

Freeman, M. C., Greene, L. E., Dreibelbis, R., Saboori, S., Muga, R., Brumback, B. & Rheingans, R. 2011 Assessing the impact of a school-based water treatment, hygiene and sanitation programme on pupil absence in Nyanza Province, Kenya: a cluster-randomized trial. *Tropical Medicine & International Health* **17** (3), 380–391.

Freeman, M. C., Garn, J. V., Sclar, G. D., Boisson, S., Medilcott, K., Alexander, K. T., Penakalapati, G., Anderson, D., Mahtani, A. G., Grimes, J. E. T., Rehfuess, E. A. & Clasen, T. F. 2017 The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *International Journal of Hygiene and Environmental Health* **220**, 928–949.

Fuller, J. A., Villamor, E., Cevallos, W., Trostle, J. & Eisenberg, J. 2016 I get height with a little help from my friends: herd protection from sanitation on child growth in rural Ecuador. *International Journal of Epidemiology* **45** (2), 460–469.

Garn, J. V., Greene, L. E., Dreibelbis, R., Saboori, S., Rheingans, R. D. & Freeman, M. C. 2013 A cluster-randomized trial assessing the impact of school water, sanitation and hygiene improvements on pupil enrolment and gender parity in enrolment. *Journal of Water Sanitation and Hygiene for Development* **3** (4), 592–601.

Geruso, M. & Spears, D. 2018 Neighborhood sanitation and infant mortality. *American Economic Journal: Applied Economics* **10** (2), 125–162. https://doi.org/10.1257/app.20150431.

Grant, M., Lloyd, C. & Mensch, B. 2013 Menstruation and school absenteeism: evidence from rural Malawi. *Comparative Education Review* **57** (2), 260–284. https://www.journals.uchicago.edu/doi/abs/10.1086/669121.

Jiang, N. M., Tofail, F., Moonah, S. N., Scharf, R. J., Taniuchi, M., Ma, J. Z., Hamadani, J. D., Gurley, E. S., Houpt, E. R., Azziz-Baumgartner, E., Haque, R. & Petri Jr., W. A. 2014 Febrile illness and pro-inflammatory cytokines are associated with lower neurodevelopmental scores in Bangladeshi infants living in poverty. *BMC Pediatrics* **14** (50).

Klasen, S., Lechtenfeld, T., Meier, K. & Rieckmann, J. 2012 Benefits trickling away: the health impact of extending access to piped water and sanitation in urban Yemen. *Journal of Development Effectiveness* **4** (4), 537–565.

Knowles, S., Lorgelly, P. K. & Dorian Owen, P. 2002 Are educationl gender gaps a brake on economic development? Some cross-country empirical evidence. *Oxford Economic Papers* **54**, 118–149.

Kosek, M. N. 2017 Causal pathways from enteropathogens to environmental enteropathy: findings from the MAL-ED birth cohort study. *EBioMedicine* **18**, 109–117.

Mbuya, M. N. N. & Humphrey, J. H. 2016 Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries. *Maternal & Child Nutrition* **12** (S1), 106–120.

Orgill-Meyer, J. & Pattanayak, S. K. 2020 Improved sanitation increases long-term cognitive test scores. *World Development* **132**, 104975.

Ortiz-Correa, J., Filho, M. R. & Dinar, A. 2016 Impact of access to water and sanitation services on educational attainment. *Water Resources and Economics* **14**, 31–43.

Park, M. J., Laksono, B., Sadler, R., Clements, A. & Stewart, D. 2015 Household latrines to control environmental contamination and helminthiasis: an exploratory study in Indonesia. *International Journal of Social Science and Humanity* **5** (5), 429–435.

Petri, W. A., Miller, M., Binder, H., Levine, M., Dillingham, R. & Guerrant, R. 2008 Enteric infections, diarrhea, and their impact on function and development. *The Journal of Clinical Investigation* **118** (4).

Petri, W. A., Naylor, C. & Haque, R. 2014 Environmental enteropathy and malnutrition: do we know enough to intervene? *BMC Medicine* **12** (1), 187.

Pinkerton, R., Oria, R., Lima, A., Rogawski, E., Oria, M., Patrick, P., Moore, S., Wiseman, B., Niehaus, M. & Guerrant, R. 2016 Early childhood diarrhea predicts cognitive delays in later childhood independently of malnutrition. *American Journal of Tropical Medicine and Hygiene* **95** (5), 1004–1010.

Rauniyar, G., Orbeta, A. & Sugiyarto, G. 2011 Impact of water supply and sanitation assistance on human welfare in rural Pakistan. *Journal of Development Effectiveness* **3** (1), 62–102.

Sclar, G. D., Garn, J. V., Penakalapati, G., Alexander, K. T., Krauss, J., Freeman, M. C., Boisson, S., Medlicott, K. O. & Clasen, T. 2017 Effects of sanitation on cognitive development and school absence: a systematic review. *International Journal of Hygiene and Environmental Health* **220**, 917–927. http://dx.doi.org/10.1016/j.ijheh.2017.06.010.

Spears, D. & Lamba, S. 2016 Effects of early-life exposure to sanitation on childhood cognitive skills: evidence from India's total sanitation campaign. *Journal of Human Resources* **51** (2), 298–327.

Trinies, V., Garn, J. V., Chang, H. H. & Freeman, M. C. 2016 The impact of a school-based water, sanitation, and hygiene program on absenteeism, diarrhea, and respiratory infection: a matched-control trial in Mali. *American Journal of Tropical Medicine and Hygiene* **94** (6), 1418–1425.

UNICEF 2018 UNICEF's game plan to end open defecation. Visit: https://www.unicef.org/wash/files/UNICEF_Game_plan_to_end_open_defecation_2018.pdf (Accessed 11 June 2020).

Vyas, S. & Kumaranayake, L. 2006 Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning* **21** (6), 459–468.

Watanabe, K. & Petri Jr, W. A.. 2016 Environmental enteropathy: elusive but significant subclinical abnormalities in developing countries. *EBioMedicine* **10**, 25–32.

Watson, T. 2006 Public health investments and the infant mortality gap: evidence from federal sanitation interventions on U.S. Indian reservations. *Journal of Public Economics* **90** (8–9), 1537–1560.

Wolf, J., Pruss-Ustun, A., Cumming, O., Bartram, J., Bonjour, S., Cairncross, S., Clasen, T., Colford Jr., J., Curtis, V., De France, J., Fewtrell, L., Freeman, M. C., Gordon, B., Hunter, P.R., Jeandron, A., Johnston, R.B., Mausezahl, D., Mathers, C., Neira, M. & Higgins, J. P. T. 2014 Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: systematic review and meta-regression. *Tropical Medicine & International Health* **19** (8), 928–942.

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