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Sanitation and child health in India

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ABSTRACT

Our study contributes to the understanding of key drivers of stunted growth, a factor widely recognized as major impediment to human capital development. Specifically, we examine the effects of sanitation coverage and usage on child height for age in a semi-urban setting in Northern India. Although sanitation – broadly defined as hygienic means of promoting health through prevention of human contact with the hazards of wastes, particularly human waste – has long been acknowledged as an indispensable element of disease prevention and primary health care programmes, a large number of recent impact evaluation studies on sanitation interventions in low income countries fail to find any health improvements. We address endogeneity of sanitation coverage through an instrumental variable approach, exploiting variation in raw material construction prices. Doing so, we find that sanitation coverage plays a significant and positive role in height growth during the first years of life and that this causal relationship holds particularly for girls. Our findings suggest that a policy that aims to increase sanitation coverage in a context such as the one studied here, is not only effective in reducing child stunting but also implicitly targets girls.

1. Introduction

The failure to reach linear growth potential early in life has been widely recognized as a major impediment to human capital development. There is increasing evidence that growth failure is correlated, likely in a causal way, with lower educational and labour market attainments as well as higher risks of health impediments such as diabetes, heart diseases and strokes (Grantham-McGregor, Cheung, Glewwe, Richter, & Strupp, 2007; Hoddinott, Maluccio, Behrman, Flores, & Martorell, 2008; Behrman et al., 2009; Maluccio et al., 2009; Victora, de Onis, Hallal, Bloessner, & Shrimpton, 2010; Adair et al., 2013; Hoddinott et al., 2013; Spears and Lamba, 2016). Rates of stunting, the general term for a child being short for its age, have been reducing over recent years, but 159 million children around the world are still estimated to be affected, more than half of these living in Asia (de Onis et al., 2015).

While a growing body of literature is contributing to our understanding of the consequences of stunting, knowledge is still limited with respect to the key drivers of low height-for-age. It is generally understood that inadequate diet and diseases are important immediate causes of stunting (Black et al., 2008; Bozzoli, Deaton, & Quintana-Domeque, 2009; Smith and Haddad, 2015); however, dealing with the endogeneity of these inputs remains a challenge in the literature (Deaton, 2007) and, with that, in informed policy decision-making. Understanding these key drivers of stunting and identifying interventions that tackle them therefore remain important points on the development agenda.

In this study, we focus on the role of diseases, by analysing the impact of an improved disease environment – specifically, an increase in the use of sanitation technology – on the growth trajectory of children under the age of 5 years. We address the endogeneity of the disease environment using prices of raw materials for the construction of toilets (cement, pipes, tiles and tin sheds) as instruments for sanitation coverage. Diseases have been linked to stunting[1] (Checkley et al., 2008) but have also shown direct associations with short-term (Nokes et al., 1992, 1998; Walker et al., 2011) and long-term effects on human capital (Bozzoli et al., 2009; Almond and Currie, 2011). Understanding the potential of improving

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[1] WHO describes stunted growth (low height-for-age) as 'a process of failure to reach linear growth potential as a result of suboptimal health and/or nutritional conditions'.

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the disease environment that children live in is hence of direct policy relevance.

The World Health Organization (WHO) identifies diarrhoea as the disease of primary concern: it is said to be the leading cause of child mortality and morbidity in the world, killing an estimated 760,000 children every year (WHO, 2013). Most of these diarrhoea cases are believed to be due to contamination of the environment. Eighty-eight per cent are seen to be linked to unsafe water, inadequate sanitation or insufficient hygiene, as estimated in a 2008 report by WHO (Pruess-Uestuen, Bos, Gore, & Bartram, 2008). More recent thinking associates lack of sanitation additionally with a gut disorder called environmental enteropathy, which in turn has been linked to impaired growth (Lunn, Northrop-Clewes, & Downes, 1991; Campbell, Elia, & Lunn, 2003; Lin et al., 2013). In fact, environmental enteropathy is now seen by many as a much larger contributor to stunting than diarrhoea (Mbuya and Humphrey, 2016). An important focus of global stunting reduction efforts has therefore been effective and affordable interventions that aim to improve the disease environment by tackling access to safe drinking water, adequate sanitation and hygiene behaviour (Mbuya and Humphrey, 2016; Cumming and Cairncross, 2016). Moreover, potential gains from access to sanitation facilities might expand to non-health-related activities such as time-use of households (Dickinson, Patil, Pattanayak, Poulos, & Yang, 2015).

While interventions that address *simultaneously* water and sanitation environment have been shown to positively affect child health (Merchant et al., 2003; WHO, 2008; Pruess-Uestuen et al., 2008; Checkley et al., 2008; Duflo, Greenstone, Guiteras, & Clasen, 2015), their relative effectiveness, and the role of improved household sanitation in particular, have proven harder to pin down.[2] While a number of studies have been able to rigorously show positive impacts of improved household sanitation (see, for example, Spears (2012), Kumar and Vollmer (2013), Pickering et al. (2015) and Dickinson et al. (2015)), many other recent randomized controlled trials (RCTs) showed no health impacts (Pattanayak et al., 2007; Clasen et al., 2014; Patil et al., 2014).[3]

Our study similarly considers the impact of sanitation on child health. However, instead of focusing on individual household sanitation ownership, we concentrate on sanitation *coverage*, in the sense of the percentage of people using a toilet in a community. The main motivation lies in the understanding that individual household sanitation is unlikely to live up to its promise of improving health statuses when (i) it is not used and (ii) neighbours are still contaminating the environment, i.e. that externalities are at play.[4] The percentage of households in a community that use a toilet is hence hypothesized to be a key driver when trying to understand the potential of sanitation in improving child health.

A number of researchers have turned their attention to linking sanitation *coverage* to child health. Most relevant in the context of our study are Spears (2012) and Hammer and Spears (2013). Exploiting the staggered introduction of India's Total Sanitation Campaign to conduct a difference-in-differences analysis, and the eligibility rules for a village sanitation prize to conduct a regression discontinuity analysis, Spears (2012) shows that infant mortality decreased by 4 per 1,000 and children's height increased by 0.2 standard deviations at the mean programme intensity.[5] Hammer and Spears (2013), concentrating on a special experimental effort in the same area of India, find through an RCT that the programme was associated with a 0.3–0.4 standard deviation increase in children's height-for-age z-scores. Dickinson et al. (2015) consider the effect of a randomized controlled trial of a community-led campaign in Orissa (India). They find that this village- rather than individual-level intervention aimed at ending open defecation increases child height-for-age by 0.37–0.52 standard deviations and weight-for-age by 0.26–0.31 standard deviations. The role of community adoption is relevant not only due to health externalities, but also because adoption has been shown to be more effective if interventions are designed at such a level (Guiteras, Levinsohn, & Mobarak, 2015; Duflo et al., 2015).

We contribute to this active and growing literature in three ways. For one, we explore the impact of sanitation coverage on child health in a (semi-)urban context by considering Indian households residing in slums and peripheral villages. Slum populations are an important group in this context since a distinctive characteristic of their environment is very crowded conditions, implying more important sanitation externality links, while at the same time experiencing on average worse access to sanitation (Buttenheim, 2008; Hathi, Haque, Pant, Coffey, & Spears, 2017). The National Sample Survey Office (NSSO, 2010) estimates that 81% of slum-dwellers in India had inadequate access to sanitation in 2008–09, which compares with national urban sanitation coverage rates of 26% in 2011. A sequence of ongoing work by the Research Institute for Compassionate Economics (r.i.c.e.) suggests that the population *density* in which children grow up is what matters most for sanitation exposure and hence impacts on health (see, for example, Coffey (2014), Hathi et al. (2014), Spears (2014) and Vyas et al. (2014)). A second reason why the slum population is particularly relevant is its fast growth. UN-Habitat (2010) estimates that 40% of the world's urban expansion is taking place in slums. At the same time, cities are struggling to keep pace with necessary infrastructure investment, leading to a phenomenon referred to as 'urbanization of poverty' – partly driven by the externalities of inadequate sanitation.

The second contribution of our study is that it identifies the marginal effect of sanitation coverage on children's growth by exploiting village-level variation in sanitation investment prices, which – as an economic model that we present highlights – determines the marginal cost of this investment and hence induces exogenous variation in the sanitation environment. We find that a 10 percentage point increase in sanitation coverage translates into an approximately 0.7 centimetre increase in height at age 4.

Finally, our third contribution is our consideration of differential effects by gender of the child. Our findings suggest that girls benefit more from an improved sanitation environment than boys, an association that has also been shown in the context of rural Ecuador (Fuller, Villamor, Cevallos, Trostle, & Eisenberg, 2016). This finding implies that sanitation investments can be used as a strategy to implicitly target girls. Such strategies can be of particular importance in a country such as India, where research has shown that boys receive higher parental investment (Barcellos, Carvalho, & Lleras-Muney, 2014).

The rest of the paper proceeds as follows. We start with an exposition of the data and study context in Section 2, followed by a discussion in Section 3 of the methodology we apply. Our

[2] Bennett (2012) in fact suggests that clean water and sanitation are substitutes in the context of the Philippines, clean water having large unintended consequences on sanitation uptake.

[3] Hypothesized reasons for this are manifold and mostly link to technological, financial and behavioural challenges.

[4] This is another possible reason why recent RCTs have failed to demonstrate health impacts of improved sanitation, namely that the coverage increase achieved was not significant enough.

[5] Other work in progress includes Geruso and Spears (2014), who use the fraction of Muslims in a village as an instrument. Gertler et al. (2015) also use an instrument in estimating the impact of open defecation rates on child health (measured by child height). Andrés, Briceño, Chase, and Echenique (2017) use a simple cross-sectional approach, not attempting to account for endogeneity in their variables of interest.

results are presented and discussed in Section 4, while Section 5 concludes.

2. Data and context

The context of our study is households residing in 39 slums and 17 peripheral, semi-urban communities (henceforth we will refer to them jointly as communities or clusters) in Gwalior, which is a historical and major city in the state of Madhya Pradesh, India. Gwalior has an estimated slum population of one-quarter of its citizens (Kumar and Aggarwal, 2008), which puts it above the country average of about 17% of urban households living in slums (2011 slum census).

At the same time, Madhya Pradesh is amongst states experiencing the worst rates of underweight and stunting for children. A nationwide survey, the Rapid Survey on Children, conducted in 2013–14 by the Ministry of Women and Child Development in cooperation with UNICEF, revealed that a staggering 41.6% of children under 5 years of age in Madhya Pradesh were stunted (18.6% severely stunted) compared with a national average of 38.7%.

Similarly, we find that 46% of children under the age of 5 years in our study population are stunted. The average height-for-age z-score, our outcome variable, is –1.6, indicating that the average child has a lower height-for-age than the reference population. Fig. 1 shows the WHO height-for-age z-score for our sample children. It can be seen that the children are already slightly short for their age just after birth and that the z-score reduces particularly in the first two years of life, after which children seem to catch up slightly again, but still staying far from the standard population.

These children live in households for which two rounds of data were collected. At the time of the first survey round (February–April 2010), a representative sample (hence both with and without children) of 1,982 households (HHs) were interviewed. During the second survey round (March–December 2013), 92% of these could be tracked and a further 204 new households were added to the sample. Our observations in this analysis consist of households with children who are 5 years or younger, providing us with a sample of 964 children from 586 households.[6]

The surveys include detailed information on households' socioeconomic status, which will be important to account for in our analysis under the presumption that it is correlated with omitted inputs and will alleviate omitted variables bias. We show statistics for these variables, together with key child characteristics, in Table 1. The information under 'BASIC' is characteristics for all households with children under the age of 5 in the communities. Statistics under 'MAIN' refer to our sample for the regression analysis. We lose about 10% of the sample in the regression analysis due to missing characteristics, which can be different for different households and children, but can be shown to be missing at random as indicated by the t-test reported in the last column.

About a quarter of sample households are Muslim; the remainder are Hindu and only for a very small percentage is the religion unknown.[7] Almost 20% of sample households belong to forward

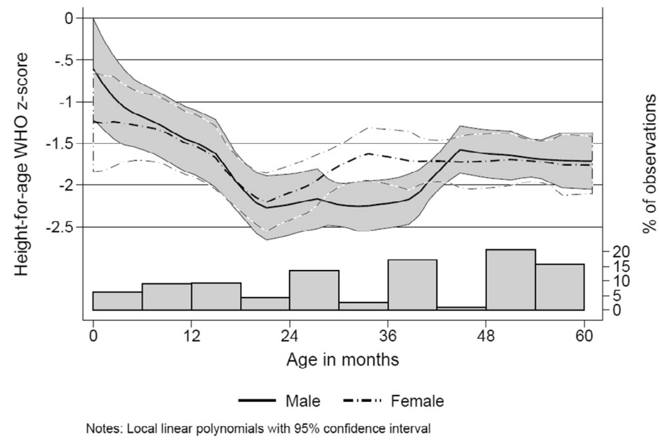

Fig. 1. Length/height-for-age z-score by age and gender.

castes, almost 30% to scheduled tribes or scheduled castes, and the remainder are from (minority) backward castes.

Our sample households have on average 6–7 household members. The main female (often the mother of the child of interest) is on average 31 years old, 1.5 m tall and uneducated. Keeping household size in mind, the households' average annual income of US$2,000 (INR 70,000) implies that our study households live much below the internationally used poverty line of US$1.25 per person per day. Most households do, however, live in a dwelling of strong or semi-strong structure, reflecting that the study slums are registered.[8]

Finally, we see at the bottom of the table that almost half of households with children aged 5 years or younger own a toilet, which they also use. At the time of the first data collection round, on average 41% of households owned a toilet, which increased to almost 60% about three years later.

The household-level toilet ownership is comparable to the community-level average, shown in Table 2, where it is also clear that almost all household members use sanitation facilities if available at their home. The table also shows descriptive statistics for our main variable of interest: the sanitation environment ES_v. We define ES_v as the percentage of households in household i's village (including i) that use sanitation infrastructure for defecation, where S_{iv} is an indicator variable equal to 1 if all members of a randomly selected household i in village v use the toilet they own or use a community toilet. The variable is 0 otherwise. I_v indicates the total number of randomly selected households in the village and N_v is the total number of households in the village.[9] We obtain $ES_v = \frac{1}{N_v}\sum_{i=1}^{I_v} S_{iv}$. In the survey, households were asked about the sanitation behaviour of groups of household members (boys, girls, male adults, female adults, male elderly and female elderly). Only if *all* of these groups were reported to use a toilet facility (their own, their neighbour's or a community toilet) is our indicator S_{iv} equal to 1 for this household. Usage of community/public toilets (or usage of neighbour's toilet) is uncommon in our sample. Fig. 2 shows a breakdown of usage rates by whether households own a toilet or not, split

[6] There are 1,915 children under the age of 5 in 56 communities. Once we consider only those for which there is raw materials price data, we have 1,342 observations in 43 communities. The number is reduced to 964 if we restrict the sample to those with valid measurements for date of birth, gender and main woman's age and height. In terms of the sample selection generated by these criteria, we are less likely to have information for the youngest children, essentially due to the difficulty of collecting anthropometrics for babies. More details on the background of this data collection exercise are presented in Appendix A.1

[7] We include this 'unknown' variable in our analysis so as not to lose these observations while at the same time being able to account for religion, which has been shown to be an important determinant of sanitation behaviour (Geruso and Spears, 2014).

[8] Being a registered slum implies legal recognition by the government and is often a prerequisite to the receipt of municipal services such as piped water, toilets and electricity.

[9] One might be concerned that this definition is correlated with household usage by construction. We therefore run our analysis with an alternative specification, excluding the respondent in the calculation of ES_v. In this definition, correlation with usage arises due to peer and contextual effects. A discussion of this analysis and results are provided in Appendix A.6 and A.7. We show that our main results are robust to this change in definition.

Table 1
Descriptive statistics – children.

	Basic		Main		
	Mean	SD	Mean	SD	TTEST
Children					
Age in months	34.5	18.2	34.8	18.2	−1.55
Female	48.1%		48.4%		−0.45
Weight-for-age z-score	−1.7	1.6	−1.7	1.6	0.05
Length/height-for-age z-score	−1.6	2.2	−1.6	2.2	−0.81
Weight-for-length/height z-score	−1.1	1.7	−1.1	1.7	0.36
Stunting: ≤ -2 SD height-for-age	46.3%		45.9%		0.58
Total children	964		864		
Social background					
Religion: Muslim	22.3%		24.1%		−3.22
Caste: forward caste	18.5%		18.7%		−0.34
Caste: minority backward caste	5.2%		5.7%		−1.62
Caste: scheduled caste or tribe	28.6%		28.8%		−0.46
HH characteristics					
Number of HH members	6.6	2.5	6.5	2.4	4.24
Number of children under 5	1.5	0.7	1.5	0.7	−0.23
Number of male HH members	3.3	1.6	3.2	1.6	3.80
Any household shock in last 12 months	9.8%		8.2%		3.96
Income†	70.1	47.6	69.0	47.1	1.90
Consumption expenditures†	101.8	81.8	97.6	76.2	3.96
Type of dwelling: strong	59.2%		56.7%		4.00
Main woman's characteristics					
Education: no formal	56.3%		56.7%		−0.68
Education: 1–5 years	14.2%		13.9%		0.65
Education: 6–8 years	16.2%		16.8%		−1.25
Education: 9 + years	13.2%		12.5%		1.70
Age (years)	31.5	10.1	31.4	10.1	1.11
Height (centimetres)	149.6	6.7	149.6	6.6	−0.81
Sanitation and hygiene					
Owns a toilet	48.8%		48.1%		1.08
Uses a toilet	47.2%		47.0%		0.27
Total households	586		515		

Notes: Own calculations based on FINISH sanitation household data for Gwalior.
† Monetary values are in thousands of Indian Rupees of 2013: R1 values were adjusted by a factor of 1.32, which was calculated based on national-level figures for 2011, 2012 and 2013.
Basic: Households for which there is information about children's and main woman's age, height and gender, and that live in a village where price data were collected.
Main: Same sample as the main regressions.
TTEST: t-statistic from a mean-comparison test between included (BASIC) and excluded (MAIN) observations.

Table 2
Communities' sanitation coverage.

	Basic		Main	
	Mean	SD	Mean	SD
Village level				
Round 1				
% of HHs whose members use a toilet	44.5	35.3	44.5	36.8
% of HHs that own a toilet	41.7	32.8	41.5	34.1
% of HHs with a toilet whose members use a toilet	98.0	4.8	98.5	3.6
Round 2				
% of HHs whose members use a toilet	56.6	30.4	56.7	31.4
% of HHs that own a toilet	59.0	27.7	59.1	28.7
% of HHs with a toilet whose members use a toilet	89.4	14.4	89.6	14.6
Both rounds				
% of HHs whose members use a toilet	51.0	33.1	51.1	34.3
% of HHs that own a toilet	50.9	31.3	51.0	32.3
% of HHs with a toilet whose members use a toilet	93.2	11.9	93.4	12.1
Villages, round 1	38		34	
Villages, round 2	43		40	
Household level, both rounds				
% where everybody uses the toilet	95.17		96.55	
% where women use the toilet	98.82		98.66	
% where girls use the toilet	95.51		96.59	
% where men use the toilet	96.08		97.25	
% where boys use the toilet	95.18		96.56	
% where grandparents use the toilet	95.17		96.55	

Notes: Own calculations based on FINISH sanitation household data for Gwalior.
Basic: Households for which there is information about children's and main woman's age, height and gender, and that live in a village where price data were collected.
Main: Same sample as the main regressions.

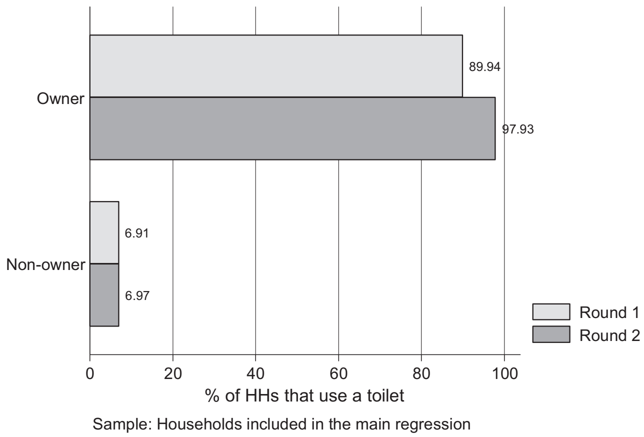

Fig. 2. Sanitation usage and ownership by survey round.

Fig. 3. Length/height-for-age z-score and sanitation environment.

by survey round. It can be seen that usage rates are driven by high usage of privately owned toilets.

Fig. 3 combines our community-level sanitation environment measure and the average height-for-age z-score for our sample children. The bars at the bottom of this figure illustrate the variation in the sanitation environment variable. It can be seen that the sample spans communities where every household reports always using a sanitation facility for defecation and communities where no household does so. Within these extremes, a wide array of usage fractions are observed in our sample. The figure gives a first graphical indication that higher sanitation usage is associated with lower stunting rates, which we will explore further in our analysis below.

3. Methodology

The principal objective of this study is to understand the relationship between community-level sanitation and child health, acknowledging that behavioural responses can induce endogeneity in our variable of interest.

Our empirical strategy is motivated by a model that combines insights from economists, demographers and epidemiologists. We take as a starting point Currie (2000)'s economic model of determinants of child health and extend it, first, by using insights from the Mosley–Chen framework (Mosley and Chen, 1984), which integrates approaches from both demographers and epidemiologists, and, second, by building on recent advances in the production function literature. Details are provided in Appendix A.2.

3.1. Estimation specification

We take our theoretical model to the data by estimating the following regression specification:

$$Q_{iv} = \alpha + \gamma ES_v + \delta_1 X^c_{iv} + \delta_2 X^{hh}_{iv} + \delta_3 X^v_v + \varepsilon_{iv}, \quad (1)$$

where Q_{iv} is the health of child i in village v. ES_v is the sanitation environment as described previously. X^c_{iv} are relevant individual, i.e. child-level, characteristics, discussed in the previous section; X^{hh}_{iv} are household-level variables, including household composition, the education and height of the main woman in the household,[10] income and shocks experienced; and X^v_v are village-level characteristics, including information on water and garbage disposal. ε_{iv} are shocks to health. The corresponding reduced form equation of the model is Eq. (13) in Appendix A.2.

In addition to emphasizing the importance of sanitation in child health production, the Mosley–Chen framework discussed the likely endogeneity of this input. For example, endogeneity might stem from households with a child who has a particularly weak immune system possibly being more likely to seek investment in infrastructure that keeps the household's immediate environment free from contaminants, contributing to a negative correlation between demand for curative health inputs and good health. This is in contrast to the anticipated positive relationship between improvements in the immediate disease environment and health if such an improvement were randomly allocated to households with equally weak children. However, this concern is less important in our framework as the variable of interest is an aggregate at village level rather than an individual choice.[11] This means that as long as health shocks and household responses to them are idiosyncratic within villages, our estimates for the impact of ES_v on health should not be biased. The real identification threat comes from aggregate shocks. Take, for example, communities with very high population density and at the same time limited public (health) infrastructure, as is often the case in slums in developing countries. One can imagine that communities faced with such conditions, which are likely to negatively impact health, are more likely to make their own investments in infrastructure improving the disease environment.

To address this endogeneity of our main variable of interest, ES_v, we employ an instrumental variable (IV) approach, estimating the following first-stage regression:

$$ES_v = \mu_0 + \mu_1 X^c_{i,v} + \mu_2 X^{hh}_{i,v} + \mu_3 X^v_v + \mu_2 Z_v + \varepsilon_{i,v}. \quad (2)$$

Our choice of instrument, Z_v, is inspired by the production function literature. In this literature, input prices are typically acknowledged to affect investment choices, as also outlined in the model (see Eq. (15) in Appendix A.2), without entering the production function directly (Heckman and Macurdy, 1986). In line, we will

[10] One could argue that better indicators to include would be the education level and height of the child's mother specifically. Our data do not allow us to identify this relationship within the household. Given household composition, we can infer that in many cases the main woman is likely to be the mother. Where this is not the case, it is likely that the mother's practices are influenced by the main woman in the household. For further discussion on the role of female height in the equation, see Appendix A.3

[11] It is important to mention that, while an analysis of the relative contributions of individual sanitation ownership and sanitation coverage is highly desirable, our specification does not allow us to do this in a credible manner. The main reason lies in the lack of exogenous variation, which induces individuals to use sanitation facilities independent of current village coverage or expected future village coverage, while at the same time being unrelated to household-level determinants of child development investment (parental health, income, education, etc.). We further discuss this issue in Appendix A.3

argue in Section 3.2 that prices for sanitation *raw* materials, which in our context exhibit sufficient geographic variation while at the same time being a significant predictor of sanitation uptake, are a suitable candidate.

Given this instrumental variable approach, our parameter of interest, γ in Eq. (1), is to be interpreted as a local average treatment effect. We are implicitly comparing the average level of child health in communities where dwellers are willing to build toilets but are restricted in doing so by the level of raw material prices and in communities where dwellers are not restricted in this way. Considering the large percentage of households in our study sample that report financial constraints to be the main barrier to sanitation uptake, we believe that this is a reasonable approach to follow. Fig. 4 shows the reported reasons why households do not own a toilet for our study population. It can be seen that for almost all households that do not own a toilet, the dominating reason for this is that the investment is too expensive, underlining the importance of prices in deciding to make the investment.[12] Other studies have shown the importance of price and credit constraints in health purchasing decisions (Dupas, 2009; Cohen and Dupas, 2010; Ashraf, Berry, & Shapiro, 2010; Spears, 2011), including a recent study that demonstrates how availability of credit increases the willingness to pay for toilets (BenYishay et al., 2016). We discuss additional topics regarding the validity of our strategy in Appendix A.3, including alternative p-values we use to adjust for small and unequal cluster sizes.

3.2. Sanitation raw material prices as instruments

The key to our identification strategy is the sanitation raw material prices we use as our instrument for sanitation coverage.

Input prices are generally acknowledged to affect investment choices without entering the production function directly and are hence used, where feasible, to instrument endogenous variables in the context of production functions and beyond (see, for example, Todd and Wolpin (2003), Puentes et al. (2016) and Attanasio et al. (2015)).

We have two types of input prices in our data: labour and construction raw materials.

Labour input prices[13] are generally problematic since they might hide worker quality, which then enters the production function through the unobservable ε_{iv} in Eq. (1). As a result, ε_{iv} is likely to be positively correlated with wages, invalidating the use of labour input prices as an instrument (Heckman and Macurdy, 1986). We therefore do not make use of these prices in our main analysis, but, as we show in Section 4.2, our results are robust to their inclusion.

Raw material input prices comprise information on the price of four important components for toilet construction (cement, pipes, tiles and tin sheds) and the quantity needed for a pour-flush pit toilet, the predominant toilet type in the sample and, in fact, in the state more generally. We aggregate this information into a single input price. These price and quantity data were collected shortly after the baseline survey by contacting a random provider of raw materials for sanitation within each cluster of the study communities. Data are available for 43 clusters in the study. More details on the collection are provided in Gautam (2016).

Table 3 gives average statistics for our available price variables. The average raw material prices for the listed toilet components amount to INR 8,300 (~US$ 178 in 2010), ranging from about INR 5,500 to INR 10,800.[14]

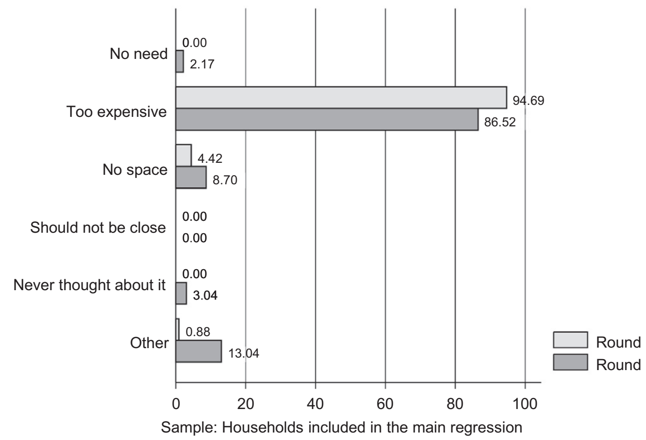

Fig. 4. Reported reasons for not owning a toilet (%).

Table 3
Toilet construction costs.

	Basic		Main	
	Mean	SD	Mean	SD
Cost of raw materials (1000 Rps)	8.3	1.7	8.3	1.7
Wages × Days required to build a toilet	0.3	0.1	0.3	0.1
Sanitation price (1000 Rps)	8.6	1.7	8.6	1.7
Villages, round 1	38		34	
Villages, round 2	43		39	

Notes: Own calculations based on toilet prices from Gautam (2016).
*Basic***:** Households for which there is information about children's and main woman's age, height and gender, and that live in a village where price data were collected.
Main: Same sample as the main regressions.

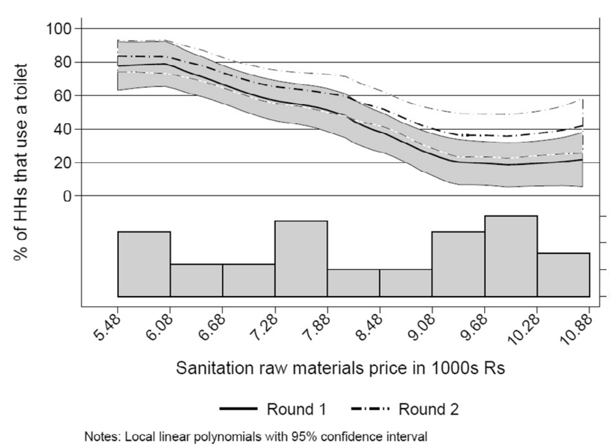

Fig. 5. Sanitation raw materials prices and sanitation uptake.

The necessary condition for this aggregate input price to be a valid instrument is that it is uncorrelated with $\varepsilon_{i,v}$. Whether this is the case depends on the competitive nature of the input market that our households are operating in and the preference structure of the slum dwellers. The sanitation supply market in Madhya Pradesh is considered well developed and competitive in nature

[12] We note that there is also a highly significant correlation between the prices of toilets and the likelihood of reporting that toilets are expensive. The results are available upon request.

[13] Specifically, we have available the approximate informal daily wage rate and the approximate time of building the standard model supported by the Government of India.

[14] We also show the estimated labour cost, which – when added to materials costs – brings the average cost up to INR 8,600.

Table 4
Raw materials price and village characteristics.

OLS regression with raw materials price as dependent variable					
	(1)	(2)	(3)	(4)	(5)
Inner Gwalior area	−1.411***	−1.423***	−1.033**	−1.020*	−0.600
	(0.459)	(0.511)	(0.449)	(0.574)	(0.529)
Village scale and location index		−0.760***			−0.488**
		(0.252)			(0.234)
General prices index			−1.013***		−0.931***
			(0.162)		(0.161)
Water and garbage disposal index				−0.522	−0.321
				(0.352)	(0.274)
No. of observations	78	69	74	75	68
No. of villages	43	37	39	40	36
R-squared	0.148	0.297	0.459	0.207	0.556

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). All specifications include a dummy for round. Standard errors clustered at village level in parentheses. Significance: * 10%, ** 5%, *** 1%.

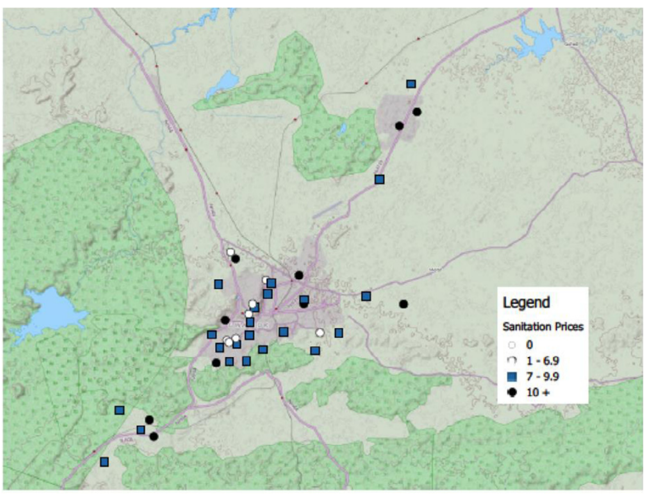

Fig. 6. Community locations and prices of sanitation raw materials.

Table 5
Sanitation environment and height-for-age.

	(1) OLS	(2) IV
Panel A: second stage % of village that use a toilet (γ)	0.004	0.017**
	(0.005)	(0.008)
p-Value for H_0: $\gamma = 0$		0.035
Analytic based on cluster-robust t-test		
Wild cluster BS t-test		0.056
Panel B: first stageSanitation raw materials price		
(1000 Rps)		−8.057***
		(2.244)
F-statistic		12.89
Observations	892	864
Clusters	41	40
Adjusted R-squared	0.11	0.10

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Controls: third-order polynomial in age, gender, main woman's education, quartiles of income, HH size, number of HH members who are male, any adverse shock in last two years, slum and wave dummies, and a factor for quality of water and garbage disposal. Wild cluster BS: p-value constructed using 999 replications of a wild restricted efficient residual bootstrap (Davidson and McKinnon, 2010) accounting for clusters as in Cameron, et al. (2008). Analytic standard errors clustered at village level in parentheses. Significance based on the analytic t-test: * 10%, ** 5%, *** 1%.

(Godfrey, 2008), providing support that individuals are price takers in this context. However, if preferences are correlated within communities, this latter assumption might break down, invalidating our instrument. We argue that even with correlated preferences, our raw materials price should remain uncorrelated with $\varepsilon_{i,v}$, since we consider input prices of materials that are not specific to toilet construction but are relevant for construction more generally. Demand for sanitation, which is growing but to date still relatively low in India, only makes up a small fraction of the construction market, and is hence unlikely to influence these construction raw material prices. It is further important to remember that we consider slum populations, which would typically build at small quantity and low costs, making their demand again unlikely to have an impact on the overall market for these materials.

A typical limitation in the use of prices as instruments is limited variation, as one tends to think of input market prices as being fairly national in scope. This limitation is not applicable in our context. The price variable displays econometrically helpful variation. We display in Fig. 5 the distribution of prices in relation to sanitation coverage in our communities, showing the distribution of observations across the x-axis. The figure shows clearly the variation in input prices across study clusters. It also shows a clear downward trend in prices: the higher the price, the lower the coverage of sanitation infrastructure.

A natural question to arise is 'What drives this variation in prices across a relatively small geographical area?'. Our analysis and discussion with experts in the field reveal that one of the main drivers is access. This is confirmed in Table 4, which shows significant correlations with variables proxying for access, particularly a dummy indicating whether the village lies within the inner Gwalior area and a village scale and location index.

The fact that prices are lower in more central areas of the city is visualized in Fig. 6, where round white dots indicate sample communities with the lowest raw material prices, almost exclusively located in the central part of the city (the area with a slightly darker shade of grey).

Table 11 in Appendix A.4 provides a breakdown of the village scale and location index. Correlations with individual components of the index are in line with the general significant correlation shown in Table 4. For example, the variable indicating whether the community is connected by local transport to the main bus stop in Gwalior has a significant and negative correlation with our price variable. The same holds for whether the cluster has its own shops and other variables proxying for better access.[15]

The correlation between our instrument and access becomes a concern when the raw materials price reflects access to other pos-

[15] The table also shows that our instrument prices correlate with other prices in the village. This is not an unexpected finding and is one we will pick up on in our robustness analysis in Section 4.2. Finally, the table also includes information on the correlation between prices and access to water and garbage disposal. These we specifically account for in our regression specification.

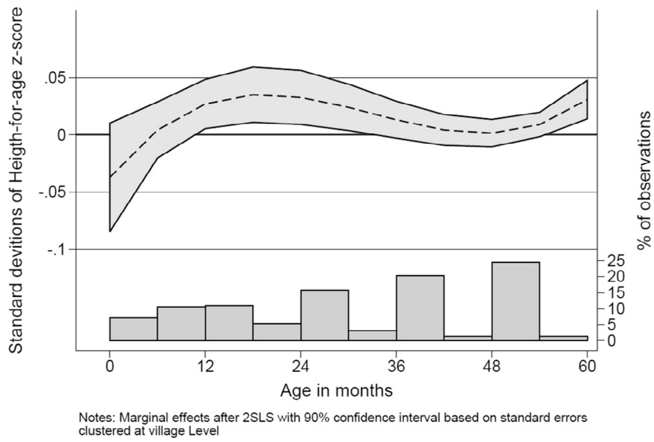

Fig. 7. Marginal effects by age.

sible determinants and correlates of child health (particularly nutritional investments such as breastfeeding or dietary diversity) not accounted for in our analysis. We take this up in Section 4.2, where we conduct robustness checks on our findings, providing additional evidence that makes us confident that our raw material prices are a suitable candidate to account for the endogeneity of sanitation coverage in our study area.

We will discuss in the next section how accounting for the endogeneity affects the findings to our main question of interest: how an improvement in sanitation coverage affects children's height-for-age.

4. Results

Our main finding is presented in Table 5, which shows the coefficient of interest, γ in Eq. (1).[16] Column (1) shows the OLS regression results, which suggest that, while positive, the impact of increased sanitation coverage on child height-for-age is small and not significant. Once accounting for the endogeneity by instrumenting with the price of raw materials, we see in column (2) that the coefficient becomes larger and is now significant at the 5% level if we consider the cluster-robust t-statistic, or 10% for the bootstrapped version.

The fact that the OLS estimate is downward biased can be understood in the context of the example given previously: it indicates that households living in communities with worse conditions for health (such as very high population density coupled with limited (health) infrastructure) are more likely to make investments in private household sanitation. This behavioural response improves the wider sanitation and hence disease environment - leading to a negative, or lower, correlation between sanitation environment and health.

The F-statistic of the IV regression is 12.89, observably lower than in the 'pure' regression, where it is 17.13, due to accounting for a large set of covariates at the child, household and community level, but still strong.[17]

The coefficient of 0.017 from the IV regression suggests that a 10 percentage point increase in sanitation usage coverage increases child height-for-age on average by 0.17 standard deviations of the z-score. To put this number in context, an increase of 10 percentage points in sanitation coverage translates into an approximately 0.7 centimetre increase for a 4-year-old. This seems a sensible finding when compared with the findings of other papers. For example, Richard et al. (2013) find – using data from seven cohort studies – that the cumulative effect on child's length from diarrhoea burden in the first two years of life is 0.38 centimetres and Hammer and Spears (2013) find that an increase in toilet ownership of 8.2 percentage points in areas of Madhya Pradesh leads to an increase in child height-for-age by 0.3–0.4 standard deviations or 1.3 centimetres when the child is 4 years old.

We conduct a number of robustness checks related to the validity of our instrument and our findings, which we discuss in detail in Section 4.2.

4.1. Heterogeneous impacts

We consider two types of heterogeneous impacts. First, we look at the marginal effects by the child's age, and second, we consider differential impacts by the child's gender.[18] We discuss the rationale for the specific choice of heterogeneous impacts and our findings first for age and then for gender. Both exercises provide interesting insight and suggestive evidence that sanitation can act both as a substitute for and as a complement to other child health investments.

The consideration of heterogeneous impacts by the child's age was triggered by a recent policy interest in the complementarity of improved sanitation and nutrition. The failure to alleviate child malnutrition in some contexts, despite improvements in nutritional intake and diets, has led to the conjecture that nutritional investments are, on their own, insufficient for improving child physical growth and need to be complemented with other investments (Mbuya and Humphrey, 2016). However, biological evidence suggests that nutrition and sanitation might actually be substitutes during certain developmental stages of the child, particularly when the child is exclusively breastfed due to antibodies in the milk (VanDerslice, Popkin, & Briscoe, 1994). Given that it is typical in our study setting for mothers to breastfeed almost exclusively for the first six months, we are interested to see whether the positive impacts of improved sanitation that we find are more pronounced when the child is older. And indeed, our analysis in Fig. 7 reveals that impacts materialize only when the child is around 6 months of age and are most pronounced until the age of 2. This period is when most placidity in growth happens (Victora et al., 2010), hence providing the largest opportunity for impacts on child height-for-age. Our study findings therefore provide support to the hypothesis that sanitation acts as an important complement to nutrition once children are no longer exclusively breastfed.

Our second heterogeneous analysis looks at the gender of the child, given that our study sample lives in an area where families are known to have explicit preferences for sons over daughters (Pande and Astone, 2007). It has further been established that such male preference translates into differential investment: 'boys receive more childcare time than girls, they are breastfed longer and they get more vitamin supplementation' (Barcellos et al., 2014). There is further evidence that boys receive more nutrition (Das Gupta, 1987), more healthcare (Basu, 1989; Ganatra and Hirve, 1994), are breastfed for longer (Jayachandran and Kuziemko, 2015) and are more likely to be vaccinated (Borooah, 2004). All these investments are known to boost a child's immune system and improve health. Consequently, preferential investment (particularly health investment) could lead to girls responding more positively to improvements in the disease environment.

[16] Full regression results, including the first stage, with information on all covariates, are shown in Table 12 in Appendix A.5

[17] It is typically said that, as a rule of thumb, the F-statistic of a joint test of whether all excluded variables are irrelevant in the first-stage regression should be bigger than 10 (Staiger and Stock, 1997).

[18] For this analysis, we include in Eq. (1) an interaction between toilet usage and the variable of interest (age or gender), and similarly interact prices. For age specifically, we interact both usage and prices with a third-order polynomial in age. The rest of the specifications remain the same.

Table 6
Sanitation environment and height-for-age by gender.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS			IV		
	Male	Female	Both	Male	Female	Both
Panel A: second stage % of village that use a toilet (γ)	0.002	0.007		0.008	0.025***	
	(0.006)	(0.005)		(0.009)	(0.009)	
Village average × Boy (β_{Boys})			0.003			0.014
			(0.005)			(0.009)
Village average × Girl (β_{Girls})			0.004			0.021***
			(0.005)			(0.008)
Girl			0.017			−0.224
			(0.208)			(0.295)
p-value for H_0: $\gamma = 0$				0.357	0.004	
Analytic based on cluster-robust t-test						
Wild cluster BS t-test				0.412	0.054	
p-value for H_0: $\beta_{Boys} = 0$						0.136
Analytic based on cluster-robust t-test						
Wild cluster BS t-test						0.148
p-value for H_0: $\beta_{Girls} = 0$						0.008
Analytic based on cluster-robust t-test						
Wild cluster BS t-test						0.022
Panel B: first stage Sanitation raw materials price (1000 Rps)				−8.252***	−8.045***	
				(2.115)	(2.309)	
F-statistic				15.22	12.13	18.65 / 12.93
Observations	459	433	892	446	418	864
Clusters	40	40	41	39	39	40
Adjusted R-squared	0.07	0.15	0.11	0.07	0.12	0.10
p-value for H_0: $\beta_{Girls} - \beta_{Boys} = 0$			0.88			0.26

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Controls: Gender, age third-order polynomial, main woman's height and age, and dummies for round 2 and for living near Gwalior centre, mother's education, quartiles of self-reported HH income and its mean, total consumption expenditures of HH in last year, quality of the dwelling, HH size, number of HH members who are male, any adverse shock in last 12 months, religion and caste dummies, and a factor for quality of water and garbage disposal. Wild cluster BS: p-value constructed using 999 replications of a wild restricted efficient residual bootstrap (Davidson and McKinnon, 2010) accounting for clusters as in Cameron, et al. (2008). Analytic standard errors clustered at village level in parentheses. Significance based on the analytic t-test: * 10%, ** 5%, *** 1%.

In line with this, our analysis of differential impacts by the child's gender reveals that the overall positive impacts of improved sanitation environments on child health are driven by impacts on girls. This can be seen in Table 6.[19] The estimated coefficient for girls is highly significant and indicates an increase of approximately 1.05 centimetres for a 4-year-old girl when sanitation usage coverage is increased by 10 percentage points, whereas boys do not seem to benefit significantly from this improvement in their environment.[20,21]

4.2. Robustness checks

We consider four robustness checks to our analysis.

The first check is to consider the impact on our estimates of the inclusion of covariates and, with that, loss of sample size due to missing information. Column (1) of Table 7 shows how our estimates differ when the BASIC set of controls is considered instead of the MAIN ones (depicted in Table 1). The full results (presented in Table 12, Appendix A.5) show that our estimates do not necessarily reflect impacts for the average household in the slums and nearby villages of Gwalior but are more likely to apply to less educated, poorer households, which are somewhat more likely to be Muslim. While this compromised external validity is an important limitation of the study, we note that this somewhat disadvantaged sample is possibly of greater interest for policymakers. At the same time, it is important to point out that the result obtained with the BASIC set of controls (and hence applicable to the whole sample) remains significant and lies within the 95% confidence interval of our main result.

The second set of checks relate back to our discussion of the validity of instruments in Section 3.2. One check was a relatively minor point, where we showed that our raw materials price index correlates with other community-level prices, such as for food items. Accordingly, when index functions of food prices are included, our coefficient of interest becomes less precisely estimated and becomes somewhat larger, confirming that part of the variation in our instrument is related to other prices. This can be seen in column (4) of Table 7.

Importantly though, our results might be biased if the driving factor for the price variation is correlated with other child health inputs not accounted for in the analysis. Specifically, we argued in Section 3.2 that the price variation is driven by access. Column (3) in Table 7 repeats our analysis while accounting for the village

[19] As in Table 5, we show both OLS and IV regression results. For both estimation approaches, we show first the subsample regressions for males (columns (1) and (4)) and females (columns (2) and (5)). Columns (3) and (6) include an interaction of our sanitation environment variable and the gender of the child.

[20] We note that this finding could be driven by differential private toilet investment by households with sons. However, Augsburg and Rodrìguez-Lesmes (2015) have shown, with the same data, that households in this context do not respond to the arrival of a new baby in the household, regardless of their gender, by constructing a toilet. We thank an anonymous referee for pointing this out.

[21] In general, we note that this analysis is not to be seen as evidence that our households practise differential investment favouring boys. Our specification does not allow us to make this statement and assessing son preferences is beyond the scope of this paper. We merely postulate this as a possible and, in our view, plausible mechanism behind our findings. The same holds for our discussion of findings by age of the child. We also explored other possible explanations, including that girls might be more directly affected than boys by the increase in sanitation usage coverage. The related hypothesis is that differential adoption/usage by women – compared with men – might increase the benefits that they receive from sanitation. Augsburg and Rodrìguez-Lesmes (2015) found a difference in the probability of having a toilet due to the number of males in the household. In general, having more men in the household, conditional on its size, is related to a lower probability of owning a toilet. Thus, this revealed preference of women for sanitation might be related to better usage patterns by girls that are not captured by our current measures.

Table 7
Sanitation environment and height-for-age – robustness checks.

	(1) BASIC	(2) MAIN	(3) LOCATION	(4) PRICES	(5) U18	(6) A18	(7) A18	(8) A18 †
Panel A: second stage % of village that use a toilet	0.012**	0.017**	0.016**	0.035	0.022	0.017**	0.001	−0.000
	(0.006)	(0.008)	(0.008)	(0.039)	(0.023)	(0.007)	(0.008)	(0.007)
General prices index (baseline)				−0.339 (0.450)				
Village scale and location index			−0.102 (0.134)					
Distance to nearest market (kilometres)			−0.006 (0.020)					
Distance to nearest health facility (km)			−0.033 (0.082)					
Dietary diversity measure							0.142*** (0.051)	
Breastfeeding					0.422 (0.377)			
Panel B: first stage F-statistic	17.13	12.89	79.91	1.28	8.94	14.97	17.00	15.94
Observations	964	864	568	820	186	664	472	472
Clusters	43	40	28	39	37	40	40	40
Adjusted R-squared	0.09	0.10	0.12	0.04	0.02	0.11	0.17	0.16

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Standard errors clustered at village level in parentheses. *Basic:* Gender, age third-order polynomial, main woman's height and age, and dummies for round 2 and for living near Gwalior centre. *Main:* The same as BASIC but also mother's education, quartiles of self-reported HH income and its mean, total consumption expenditures of HH in last year, quality of the dwelling, HH size, number of HH members who are male, any adverse shock in last 12 months, religion and caste dummies, and a factor for quality of water and garbage disposal. *Location, prices***:** MAIN specification augmented with the specific index. **U18:** Age 18 months or younger. **A18:** Age above 18 months. † Same sample as in column (7); the non-inclusion of dietary index is the sole difference. Significance: * 10%, ** 5%, *** 1%.

scale and location index, which we showed earlier to be significantly correlated with our price variable. In addition to this index, the regression includes other village-level variables, whose omission could be driving our results. These variables are the distance to the main market in the community and the distance to the closest health services facility (either public or private hospitals, clinics or health centres). Both variables, measured in kilometres, are part of the community module questionnaire. While the sign is negative as expected, we cannot statistically reject that their relationship with child health is different from zero and our estimated coefficient remains equivalent in magnitude. It becomes slightly less precisely estimated, which might be driven by the reduced sample size, which is due to the lack of this additional information for some communities.

The third robustness test considers similarly the relevance of omitted variables important in determining child health, namely nutrition. Unfortunately, although we have some information available, it does not allow us to draw any strong conclusions. The surveys collected information on whether infants (18 months or younger) are breastfed and on what types of food children older than 18 months ate the day before the survey. Using these data comes with two main sacrifices. For one, including the information in our analysis reduces the sample to either infants or older children, thus significantly reducing our sample size and, with that, power. Splitting the sample into these two age groups, however, suggests that the impacts are driven by older children, as can be seen from columns (5) and (6) of Table 7. Focusing on these older children, we can use their nutrition information data to construct a dietary diversity index and include it in the regression to check for omitted variable bias (keeping in mind that this variable is likely to be endogenous itself!). The second caveat is that we are faced with systematic non-reporting. We find that item non-response in children's consumption is related to household and child characteristics (age and gender of the child, age of the main woman (mother), and household size). When including the dietary diversity measure in our regression specification (column (7)), we find that the impact of sanitation coverage on child health disappears. However, running our main specification (i.e. excluding the dietary diversity index) on only those children for whom we have consumption data available (column (8)), we see that we similarly do not find impacts of sanitation coverage. This indicates that by including dietary diversity in the analysis, we are positively select-

Table 8
Nutrition investments and raw materials price.

Sample: children aged 0 to 18 months (for breastfeeding) and 18 to 60 months (for dietary diversity)

	(1)	(2)	(3)	(4)	(5)	(6)
	Breastfeeding			Dietary diversity		
	ALL	HH Cont	MAIN	ALL	HH Cont	MAIN
Panel A	−0.006	−0.012	−0.019	0.053	0.101*	0.094
Raw materials price index						
	(0.012)	(0.013)	(0.017)	(0.054)	(0.053)	(0.057)
Observations	300	230	186	627	520	463
Clusters	41	38	37	43	40	40
Adjusted R-squared	0.10	0.10	0.06	0.01	0.07	0.06
Panel B	−0.001	−0.000	−0.000	−0.002	0.000	0.001
% of village that use a toilet						
	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.003)
Observations	425	234	190	914	537	479
Clusters	54	39	38	56	41	41
Adjusted R-squared	0.11	0.11	0.07	0.02	0.05	0.05

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). **ALL:** All children for whom there is information on age and gender. It also includes slum and wave dummies. *HH Cont:* These regressions include main woman's education, quartiles of income, HH size, number of HH members who are male, any adverse shock in last 12 months, and a factor for quality of water and garbage disposal. *Main:* Children who, on top of the previous controls, have a valid measure of height-for-age. Standard errors clustered at village level in parentheses. Significance: * 10%, ** 5%, *** 1%.

Table 9
Sanitation environment and height-for-age with alternative prices as instrument.

	(1) MAIN	(2) Rp&Lp	(3) Lp
Panel A: second stage % of village that use a toilet	0.017**	0.017**	0.030
	(0.008)	(0.008)	(0.035)
Panel B: first stage F-statistic	12.89	11.18	0.71
Observations	864	864	864
Clusters	40	40	40
Adjusted R-squared	0.10	0.10	0.06

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Standard errors clustered at village level in parentheses. *BASE:* Gender, age third-order polynomial, main woman's height and age, and dummies for round 2 and for living near Gwalior centre. *MAIN:* The same as BASE but also main woman's education, quartiles of self-reported HH income and its mean, total consumption expenditures of HH in last year, quality of the dwelling, HH size, number of HH members who are male, any adverse shock in last 12 months, religion and caste dummies, and a factor for quality of water and garbage disposal. **Rp&Lp:** Total price of sanitation as an instrument (includes labour and raw materials). **Lp:** Labour price only as an instrument. Significance: * 10%, ** 5%, *** 1%.

ing into our analysis those children who are of better health and consequently likely to be less affected by the protective power of sanitation.

As an additional check, we look at the correlation between our instrument and dietary diversity and breastfeeding, as well as their correlation with ES_v. We can do this for three samples depending on the regression specification: first, all children for whom dietary information (or breastfeeding) as well as age and gender is available; second, those for whom we also have the covariates that are included in our main regression analysis; and third, those children for whom we also have valid height-for-age measurements. Results are displayed in Table 8. It can be seen that correlations in all three cases suggest, if anything, that our raw materials price is positively correlated with dietary diversity, generating a downward bias on our estimates.

Finally, for our fourth robustness check, we use as instrument not just the raw materials price but also labour wages. As discussed in Section 3.2, inclusion of labour prices might invalidate using prices as instruments. We consider the impact of this alternative construction of the index in Table 9 and find that the main effect remains the same. The reason for this is the limited impact of wages on actual sanitation coverage, as shown in the first stage of column (3).

5. Conclusion

We make use of primary data collected as part of an evaluation exercise for a sanitation intervention to investigate the impact of improvements in the sanitation environment, defined as the fraction of households using private or community toilets, on child height-for-age, an indicator for health.

We do so in the context of slums and peripheral villages in Gwalior, a city in Northern India. This population is an important one to consider for two main reasons: India's slum population is growing rapidly while at the same time having no or only inadequate access to safe sanitation. High population density coupled with improper means of disposal for faeces provides a breeding ground for preventable disease epidemics. Providing evidence on improvements in children's health that can be achieved by community-level sanitation improvements is hence of direct policy relevance. Despite the fact that our sample lives in a crowded setting, our estimated impacts are only half as big as those of Hammer and Spears (2013), Richard et al. (2013) and Dickinson et al. (2015), who found impacts of improved sanitation on height-for-age of around 0.2–0.4 standard deviations in rural areas of India. This stresses the difficulty of extrapolating effect sizes from one setting to another (even within India) and highlights the need for more research on this topic in order to gain a comprehensive understanding of the burden of open defecation on child development.

Our study further reveals two policy-relevant differential impacts. First, we provide supportive evidence that sanitation acts as a complement to nutrition once children are no longer exclusively breastfed. This suggests that targeting families of newborns with the message of how important a clean environment will be for their growing child might be particularly fruitful. Second, we show that improved sanitation seems to be particularly relevant for girls, suggesting not only that investment in sanitation coverage is worthwhile when children's health is one of the objectives, but that increasing sanitation coverage seems at the same time to be a policy that implicitly targets girls.

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Conflict of interest

None.

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Appendix A

A.1. Data background

The original purpose of these data was to evaluate a sanitation intervention called FINISH (FINancial Inclusion Improves Sanitation and Health), implemented by the voluntary organization Sambhav in Gwalior (Madhya Pradesh).[22] The intervention focused primarily on the uptake of private household sanitation through awareness creation as well as the provision of loans for the investment. The evaluation design was a randomized controlled trial, with clusters as the unit of randomization. The randomization took place towards the end of January 2010 and the baseline survey took place between February and April 2010. Details on the intervention, design and data collection are available in the FINISH Impact Evaluation Report (Augsburg and Rodrìguez-Lesmes (2015)). Toilet ownership was assessed by asking the respondent in the household. In the follow-up questionnaire, the exact wording is: *Does your household own a toilet (note that this is different from 'using the toilet')?* If there is a toilet, there are questions on its structure and then on its use: *Is the toilet currently being used by some or all of the household members?*

[22] Sambhav engages in issues of female empowerment, health, sanitation, education and violence against women, through direct programme intervention and policy-level advocacy. It works in about 1,500 villages and slums in Madhya Pradesh and Uttar Pradesh, primarily with Sahariya Adivasis, women, dalits, children and the disabled.

Everybody, women, girls, men, boys, grandparents, other. For those without a toilet, they are asked about their alternatives: *You said that your household does not own a toilet or that some of the household members do not use the toilet. Where do these household members go to urinate/defecate?* The sanitation module of the questionnaire also includes several questions on hygiene, funding of facilities and perceptions. At the end of the survey, interviewers also have to register their observation: *Does the household have a toilet?* This question allows us to assess the quality of responses.

After the baseline survey, the implementing partner started to offer sanitation loans in the selected study areas and to conduct some awareness creation activities alongside. However, implementation in the initial months was expectedly slow due to it being the monsoon and summer period. And, when the time came for lending and sanitation construction to pick up, the 2010 microfinance crisis as well as the financial crisis put a spanner in the works. This crisis and its impact on the project are discussed in more detail in the endline report (Augsburg and Rodrìguez-Lesmes (2015)). In brief, many Indian microfinance and other lending institutions, including our implementing partner, faced issues of raising funds, expanding operations etc. – all for an uncertain period (and also coinciding with the financial crisis, which made raising funds even more difficult). The impacts were felt for a long period.[23] No funding for the implementing partner implied no intervention, not only affecting the timeline of the second data collection round but also having obvious implications for the evaluation studies.

Around October/November of 2012, the situation had somewhat improved and the research team, together with the implementing agency, took stock of the situation. A list of activities was provided by the implementing partner indicating all areas in which sanitation awareness creation activities had taken place and, if appropriate, where sanitation loans had been disbursed. The data provided by the implementing partner showed that activities had taken place in 2 (out of 28) control clusters and all 29 treatment ones. It was therefore decided to go ahead with the endline survey, which was implemented between March and December 2013.

The endline analysis, however, revealed two important observations. For one, no impacts whatsoever were found from the intervention on toilet uptake (as well as other outcome measures considered, such as usage). More concerning for the validity of the evaluation design was the fact that household members in both treatment and control clusters were equally likely to report having heard of and attended sanitation activities conducted in their community, including activities that are relatively specific to the FINISH intervention such as film showings.

Through further discussion with the implementing partner, it became clear that due to the slowness of activities and lending during the microfinance crisis, Sambhav was eager for any funds and support and it conducted a number of sanitation activities for the government as well as UNICEF. Unfortunately, when conducting these, it did not take into account the treatment allocation for the FINISH evaluation study. Most unfortunate was that this had not been reflected in the data provided in October 2012. Based on the findings from the data and information received retrospectively from Sambhav, it became clear that the identification strategy to measure the impacts had been sacrificed and the impact of the intervention could not be established.

Turning to an instrumental variable approach to understand nevertheless the impact of improvements in sanitation at the community level was therefore considered.

[23] As stated in the 2011–12 FINISH Annual Reprot (2012), 'The financial crisis coupled with the microfinance crisis in Andhra Pradesh continues to rock the MFI sector. Commercial financing of MFIs virtually ceased from the last quarter of 2010 onwards'.

A question arises as to whether these activities might have influenced prices for raw materials. Given that the data we use were collected shortly after the baseline survey, this is unlikely and is confirmed in regression analysis in Table 10, where the number of villages is 40 (instead of 56 as we do not have prices for all villages and as not all villages from the baseline survey were included in the final randomization. We therefore consider the activities that took place to be activities that were generally ongoing in the country.

A.2. Simple economic model for determinants of child health

The principal objective is to understand the relationship between community-level sanitation and child health, acknowledging that behavioural responses can induce endogeneity in our variable of interest.

Mosley and Chen (1984) suggested a useful framework for us to build on. Their framework, which integrates approaches from demographers and epidemiologists, identifies a set of exogenous and endogenous determinants of child health and survival, acknowledging the role of household and community sanitation in determining child health and survival. Factors identified as exogenous include individual and household characteristics such as maternal education, income and family composition, institutional factors such as community infrastructure, ecological factors such as rainfall, and cultural factors such as traditions and norms. Factors identified as endogenous are referred to as proximate determinants and include breastfeeding and household sanitation ownership. Combining insights from this framework with those from recent advances in the understanding of human capital production functions is useful in guiding the choice of variables to include in the estimation and in understanding which variables are likely to be endogenous and whether important determinants have been omitted. We extend Currie (2000)'s economic model of the determinants of child health in this direction. In this unitary household model, parents maximize the following objective function:

$$\sum_{t=1}^{T} E_t \beta^t U_{ivt} + B(A_{iv,T+1}). \tag{3}$$

In this household i in village v, the parents are altruistic and get utility from their children's health status and the bequest, B, they leave to them. Period-specific utility is given by

$$U_{ivt} = U(Q_{ivt}, S_{ivt}, C_{ivt}, L_{ivt}; X_{ivt}, u_{1iv}, \varepsilon_{1ivt}) \tag{4}$$

where Q_{ivt} is child health, C_{ivt} is other consumption and L_{ivt} is leisure; taste for them might differ according to some observed (X_{ivt}) and unobserved characteristics (u_{1iv}) and shocks (ε_{1ivt}). On top of this, households get utility from having access to a sanitation facility S_{ivt}. Reasons for this direct benefit of sanitation might include comfort, social status and security, as well as health considerations of the adults.

In the original model by Currie (2000), the evolution of child health is shaped by parental physical (G_{ivt}) and time (V_{ivt}) investments. Parents' productivity depends on observed (Z_{ivt}) and unobserved (u_{2iv}) characteristics as well as unobserved shocks (ε_{2ivt}). We extend the model to include an additional element: namely, what we term the 'sanitation environment', ES_{vt}. We define this term as the percentage of households in the village (including i) that use sanitation infrastructure for defecation, where S_{ivt} is an indicator variable equal to 1 if all members of a randomly selected household in village v use the toilet they own or use a community toilet. The variable is 0 otherwise. I_v indicates the total number of randomly selected households in village v, which is inhabited by N_v households. We get

Table 10
Raw materials price and treatment allocation.

OLS regression with raw materials price as dependent variable	
	(1)
Whether village was in the treatment group	0.245 (0.507)
Inner Gwalior area	−1.338** (0.526)
Number of villages	40
R-squared	0.142

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Standard errors clustered at village level in parentheses. Significance: * 10%, ** 5%, *** 1%.

$$ES_{vt} = \frac{1}{N_v}\sum_{i=1}^{I_v} S_{ivt}. \quad (5)$$

This definition is driven by our interest in the role of infrastructure that isolates human waste (faeces) from the environment, i.e. sewage disposal, community toilets and private household toilets. More specifically, we are interested in the *usage* of such facilities[24] – primarily private household sanitation, but also the less common usage of community toilets and neighbours' toilets.

The Mosley and Chen (1984) framework defines sanitation ownership as a proximate determinant of child health, acknowledging its importance in providing a hygienic environment as well as the fact that it is likely to be endogenous. For example, endogeneity might stem from households with a child who has a particularly weak immune system possibly being more likely to seek investment in infrastructure that keeps the household's immediate environment free from contaminants, contributing to a negative correlation between demand for curative health inputs and good health. This is in contrast to the anticipated positive relationship between improvements in the immediate disease environment and health if such an improvement were randomly allocated to households with equally weak children.

In our definition of disease environment, we go beyond the immediate disease environment of the household, acknowledging that toilet ownership and usage provides a direct benefit as well as an external benefit, which is believed to be substantial (Gertler et al., 2015; Geruso ans Spears (2014); Duflo et al., 2015). Using a toilet reduces one's own contact with faeces in addition to other private benefits that a toilet might provide (time saving, privacy, etc.). It further reduces the rate of open defecation, which is believed to be a major cause of parasite infections and diarrhoea, particularly observed in children under 5 years of age.

It is hence not just one's own toilet usage behaviour that determines health, but also the behaviour of neighbours and community members. As is the case for the individual ownership of sanitation infrastructure discussed by Mosley and Chen (1984), this broader definition of sanitation environment is also likely to be endogenous. Take, for example, communities with very high population density and at the same time limited public (health) infrastructure, as is often the case in slums in developing countries. One can imagine that communities faced with such conditions, which are likely to negatively impact health, are more likely to make their own investments in infrastructure improving the disease environment. We will therefore need to deal with the likely endogeneity of ES_{vt}.

Including this variable in Currie (2000)'s model of child health, we get a health production function that is a function of sanitation coverage. In other words, one of the relevant determinants of child health is determined at the village level. Depending on $f(\cdot)$, individuals might control this input or not. As a result, the health production function takes the following structure:

$$Q_{ivt} = f(Q_{iv,t-1}, G_{ivt}, ES_{vt}; Z_{ivt}, u_{2iv}, \varepsilon_{2ivt}). \quad (6)$$

The rest of the model follows Currie's structure. Parents get income from working H_{ivt} hours (where available time is normalized to unity), which reduces the amount of time available for leisure as well as investments in the child's health. Physical resources are distributed among savings, child investments, a one-off sanitation investment T_{ivt} and consumption C_{ivt}. Relative to the standardized prices of other consumption, prices P^G_{vt} of child investments G_{ivt} and price P^T_{vt} of toilet construction determine the marginal cost of both investments. Notice that once a household builds a toilet, its sanitation environment is assumed to improve permanently in the following period, through the personal ownership as well as the externality effect. This reflects the fact that gains from sanitation might not be immediate. These physical resources grow with income Y_{ivt}, which can come from work at a wage w_{vt}, from capital A_{ivt} rent at a rate r, or from other source I_{ivt}. The related equations are

$$C_{ivt} = Y_{ivt} - P^G_{vt}G_{ivt} - P^T_{vt}T_{ivt} - (A_{iv,t+1} - A_{ivt}) \quad (7)$$

$$Y_{ivt} = I_{ivt} + w_{vt}H_{ivt} + rA_t \quad (8)$$

$$1 = L_{ivt} + V_{ivt} + H_{ivt} \quad (9)$$

$$S_{ivt} = max(S_{iv,t-1}, T_{iv,t-1}) \quad (10)$$

The model can be solved, as in the original set-up, to yield Frisch demand functions. Within these, λ denotes the marginal utility of wealth and M corresponds to a vector of moments of the distribution of future observed and unobserved variables $\{X_{iv\tau}, Z_{iv\tau}, P_{v\tau}, \varepsilon_{2iv\tau}, \varepsilon_{1iv\tau}, S^{-i}_{iv\tau}\}^T_{\tau=t+1}$. Here, $S^{-i}_{iv\tau}$ is a vector that incorporates the sanitation status of all other households in village v, and P_{vt} is a vector of prices (including wage) at the village level for a given period t.[25]

The Frisch demand functions are of the following form:

$$C_{ivt}, H_{ivt}, T_{ivt}, G_{ivt} \text{and} V_{ivt} = F(\beta, r, \lambda_{ivt}, X_{ivt}, Z_{ivt}, S^{-i}_{ivt}, P_{vt}, ES_{vt}, u_{1iv}, u_{2iv}, \varepsilon_{2ivt}, \varepsilon_{1ivt}, M_{ivt}). \quad (11)$$

Given these, we can substitute both physical and time inputs into the health production function, Eq. (6). If we also substitute for λ_{ivt} using the budget constraint, and assuming that M_{ivt} and A_{ivt} are functions of realizations of current and past exogenous variables $J_{ivt} = \{X_{iv\tau}, Z_{iv\tau}, P_{v\tau}, I_{iv\tau}, \varepsilon_{2iv\tau}, \varepsilon_{1iv\tau}, S^{-i}_{iv\tau}\}^t_{\tau=1}$ and A_{iv0}, we get

$$Q_{ivt} = f'(Q_{iv,t-1}, A_{iv0}, \beta, r, I_{ivt}, X_{ivt}, Z_{ivt}, S^{-i}_{vt}, P_{vt}, ES_{vt}, u_{1iv}, u_{2iv}, \varepsilon_{2ivt}, \varepsilon_{1ivt}, J_{ivt}) \quad (12)$$

and iterating over Q results in

$$Q_{ivt} = f'(Q_{iv0}, A_{iv0}, \beta, r, I_{ivt}, X_{ivt}, Z_{ivt}, S^{-i}_{ivt}, P_{vt}, ES_{vt}, u_{1iv}, u_{2iv}, \varepsilon_{2ivt}, \varepsilon_{1ivt}, J_{ivt}). \quad (13)$$

This reduced form equation of the production function makes it clear that there is a link between sanitation prices and health. This link arises because of the reduced marginal cost of building a toilet, which increases the demand for toilets.

A reduced form expression for toilet ownership can also be derived:

[24] One of the reasons put forward for the lack of impacts on health in, for example, the study by Clasen et al. (2014) is that the constructed toilets were not used.

[25] Notice that if household i has an important weight in determining $ES_{vt}, S^{-i}_{iv\tau}$ might be a function of $\{X_{iv\tau}, Z_{iv\tau}, P_{iv\tau}, \varepsilon_{2iv\tau}, \varepsilon_{1iv\tau}\}^T_{\tau=t+1}$. Given this, household *i*s best response implies that the demands should include moments for all future variables of all individuals in the village $\{\{X_{Iv\tau}, Z_{Iv\tau}, P_{Iv\tau}, \varepsilon_{2Iv\tau}, \varepsilon_{1Iv\tau}\}^T_{\tau=t+1}\}^{I_v}_{I=1}$. Here, for simplicity, we assume that this household has virtually no power in determining everyone else's adoption decision and that $S^{-i}_{iv,t+1}$ can be forecasted with some village characteristics.

$$T_{ivt} = T(A_{iv0}, \beta, r, I_{ivt}, X_{ivt}, Z_{ivt}, S_{ivt}^{-i}, P_{vt}, ES_{vt}, u_{1iv}, u_{2iv}, \varepsilon_{2ivt}, \varepsilon_{1ivt}, J_{ivt}). \quad (14)$$

As a result of the above, sanitation environment at the village level is determined by a full set of present and past states $\theta_{vt} = \{Q_{iv0}, A_{iv0}, \{X_{iv\tau}, Z_{iv\tau}, I_{iv\tau}, \varepsilon_{2iv\tau}, \varepsilon_{1iv\tau}, S_{iv\tau}^{-i}\}_{\tau=1}^{t}\}_{i=1}^{I_v}$, which includes village-level characteristics, and, importantly for our subsequent analysis, village-specific vector prices:

$$ES_{v,t+1} = f(\beta, r, S_{1vt} \ldots S_{I_v vt}, \theta_{vt}, P_{vt}). \quad (15)$$

The model shows us that both the health production function and the demand for toilet ownership are influenced by unobserved idiosyncratic persistent and transitory shocks, by initial conditions and by the history of exogenous variables, which might only be partially unobserved. Our goal is to identify $E[\partial Q_{ivt}/\partial ES_{vt}]$ and, given the presence of confounders, we will identify this marginal effect by exploiting village-level variation in P_{vt}, which induces exogenous variation in ES_{vt}. Notice that an additional channel is still open: the functional form of $U(\cdot)$ might imply that the demand for physical investments might be directly affected by the price of sanitation – for instance, with a CES specification. Such effects are expected to operate in the opposite direction to ES_{vt}, as lower prices of raw materials will induce less physical investment, reducing Q_{ivt}. If that is the case, our estimates would provide a bound on the impact of sanitation environment. Another issue is if ES_{vt} and the other inputs are substitutes or complements in the production function, which will imply different allocation of the inputs given the endogenous variation in ES_{vt}. In the most extreme scenario, all the impact on health would be driven by agents who invest more in their children, believing that the productivity of such investment is going to increase. Such questions on the functional form are beyond the scope of this paper.

In order to provide an estimate of such impacts, given the limitations of the data, we will impose some restrictions. First, $P_{vt} = P_{v,t-1}$, as we do not have variation over time for this vector. Second, we will assume that the relationship between sanitation environment and prices, as well as that between child health and sanitation environment, is as good as linear. These strong assumptions restrict the analysis and avoid potentially key elements such as non-linearity between ES_{vt} and Q_{ivt}. Nevertheless, they allow us to get an idea of the strength of the link between both variables.

A.3. Additional remarks on the empirical strategy

The use of fixed effects

We are not able to apply fixed effects regression in our analysis for a number of reasons. For one, the survey itself was not designed to track children, but rather households. This implies that we need to match children based on names recorded in the two survey rounds, which provides imperfect fit. In addition, given that three years passed between the two survey rounds, most children would not have fallen into the 0–5-year age category in both survey rounds. Both of these reasons lead to important impediments to using the data in a panel context and including fixed effects in our regression specification. Fixed effects are often included to account for genetic endowment (see, for example, Puentes et al. (2016)). As we cannot do this, we proxy for the child's health endowment by controlling for the mother's height. This would primarily proxy for heritable endowment, which is seen as an important, unobserved determinant of child health. Medical papers suggest that 60–80% of height variation is determined by genetic factors (Ginsburg, Livshits, Yakovenko, & Kobyliansky, 1998; Silventoinen, 2003). Ideally, we would like to also include the height of the child's father. Unfortunately, anthropometrics of male adult household members were not collected. It is, however, quite common to use only one parent's measure as a proxy for inherited endowment. This is also the case in the literature on early childhood development and education production functions, where, for example, the mother's AFQT score (or Armed Forces Qualification Test) is commonly used to proxy for genetic endowment of the child (Todd and Wolpin, 2003). Accounting for the mother's height at the same time allows us to proxy for a history of past inputs into child height, since we do not have available the child's height-for-age in the previous period.

The role of individual toilet ownership

Notice that our model considers that the effect of individual sanitation usage S_{iv} is just to increase sanitation environment ES_v. In other words, households with and without a toilet do not get different returns from the same village aggregate. While it is an important hypothesis to test, our data do not allow us to do so, essentially because both variables are related by definition. As a result, it is not possible to obtain an exogenous variation that modifies independently one or the other. In particular, and as normally used in the production function literature, prices are instruments of individual investment. While it would be possible to define ES_v in a way that does not include S_{iv} (see Appendix A.6), private investment is still likely to be correlated between households within the same village for several reasons, such as social status. The most extreme scenario would be that individual toilet usage generates no health externalities at all, which would mean that we were obtaining a downward bias on the effect of individual usage.

Cluster sizes

The coefficients of the model based on Eqs. (1) and (2) are estimated via two-stage least squares and standard errors are clustered at village level. One potential concern is related to the number of clusters in our regressions. We have around 40 villages in our main regressions, which is close to the typically suggested rule of thumb that 42 clusters are sufficient for reliable inference (Bertrand, Duflo, & Mullainathan, 2004; Angrist and Pischke, 2008; Ozler, 2012). However, recent research suggests that this 'rule of 42′ breaks down when the number of observations varies between clusters (MacKinnon & Webb, 2016). We will therefore – in addition to the p-values based on analytic tests – present p-values based on Davidson and Mackinnon (2010)'s restricted efficient residual bootstrap (999 replications) with Cameron, Gelbach and Miller (2008)'s adjustment for clusters.[26] Our results continue to hold independent of the p-values considered.

A.4. Village scale and location, general prices, and water and garbage disposal indices

We constructed three indices which summarize a large set of variables that might be related to price variations. Table 11 shows the components of the indices, which were selected in two steps. First, each individual component from a large list of reported variables at baseline was regressed against the raw materials price. Those variables that were significantly correlated with this variable at least the 90% level were selected for the second stage, a principal factor analysis (Stata 14 ***factor*** command), where the first factor was retained for each of the three categories. More details of this procedure are available upon request; the routine for its implementation is part of the replication files for this paper.

[26] We also implemented – with similar results – Davidson and Mackinnon (2010)'s restricted residual bootstrap (without the weak-instrument adjustment) and Cameron, Gelbach and Miller (2008)'s procedure without the IV adjustments suggested by Davidson and Mackinnon (2010).

Table 11
Components of the indices.

Variable	Mean (1)	SD (2)	Correlation with raw materials price (3)	Correlation with its index (4)
Village scale and location index				
Were new dwellings built in this village in the last 12 months?	0.075	0.267	−0.297***	0.587***
Are autos available to drive to this bus stop?	0.875	0.335	−0.323***	0.223***
Village has kirana/general market shop?	0.951	0.218	−0.269***	0.251***
Village has wine shop?	0.400	0.496	−0.289***	0.796***
Village has tailoring shop?	0.750	0.439	−0.396***	0.582***
Village has fair price shop?	0.500	0.506	−0.320***	0.786***
Village has paan shop?	0.475	0.506	−0.316***	0.670***
Village has mahila mandal?	0.150	0.362	0.324***	0.115***
Village has community centre?	0.175	0.385	−0.272***	0.627***
Village has library?	0.050	0.221	−0.302***	0.421***
Village has panchayat office?	0.250	0.439	0.315***	0.186***
Village has fans associations?	0.350	0.483	−0.305***	0.578***
Village has playground?	0.350	0.483	0.292***	0.357***
General prices index				
Price of 1 kg sugar from market	40.200	3.757	−0.358***	0.483***
Price of 1 l edible oils	55.050	6.664	0.333***	−0.465***
Price of 1 kg onions	14.925	4.015	−0.380***	0.427***
Price of 1 kg chicken	101.250	30.900	−0.508***	0.899***
Price of 1 kg tea	30.175	61.096	−0.522***	0.877***
Water and garbage disposal index				
Throw kitchen garbage away in waste baskets/trucks pick it up?	0.293	0.461	−0.328***	0.887***
Does the village community get water for cooking and drinking from hand pump?	0.537	0.505	0.433***	−0.249***
Does the village get water for cooking/drinking from household service connection	0.390	0.494	−0.317***	0.945***

Significance level: *10%, **5%, ***1%.

A.5. Full regression results – main specification

Table 12

Table 12
Sanitation environment and height-for-age (detailed).

	(1) OLS	(2) IV first stage	(3) IV second stage
% of village that use a toilet	0.004		0.017**
	(0.005)		(0.008)
Cost of raw materials (1000 Rps)		−8.053***	
		(2.242)	
Girl	0.040	0.787	0.083
	(0.125)	(1.062)	(0.124)
Age in months	−0.203***	0.362	−0.212***
	(0.055)	(0.335)	(0.055)
Age in months^2 (100 s)	0.606***	−1.447	0.636***
	(0.192)	(1.279)	(0.193)
Age in months^3 (10000 s)	−0.513**	1.557	−0.543***
	(0.190)	(1.317)	(0.190)
Main woman's height (cm)	0.045***	−0.258*	0.048***
	(0.012)	(0.129)	(0.012)
Main woman's age	0.007	0.050	0.007
	(0.008)	(0.072)	(0.008)
Inner Gwalior area	−0.406***	12.730	−0.689**
	(0.148)	(7.623)	(0.273)
Baseline observation	−0.966***	−13.013***	−0.861***
	(0.277)	(2.964)	(0.293)
Main woman's education: 6–8 years	0.081	2.632	0.007
	(0.266)	(2.445)	(0.278)
Main woman's education: 9 + years	0.047	0.570	−0.031
	(0.257)	(2.101)	(0.263)
HH self-reported income	−0.000	0.002	−0.000
	(0.003)	(0.046)	(0.003)
Total consumption expenditures of HH in last year	0.001	0.016*	0.001
	(0.001)	(0.009)	(0.001)
Income: 40.15–60.00 K INR	−0.055	−2.660	0.003

Table 12 (*continued*)

	(1) OLS	(2) IV first stage	(3) IV second stage
	(0.182)	(2.480)	(0.189)
Income: 60.25–90.00 K INR	0.231	−1.567	0.187
	(0.250)	(3.749)	(0.249)
Income: 90.30–280.00 K INR	0.507	−3.297	0.500
	(0.398)	(6.945)	(0.415)
Type of dwelling: strong	−0.098	5.967	−0.207
	(0.256)	(4.790)	(0.283)
Type of dwelling: semi-strong	−0.282	−0.526	−0.266
	(0.218)	(3.926)	(0.227)
Number of HH members	−0.110**	0.057	−0.130***
	(0.048)	(0.373)	(0.048)
Number of male HH members	0.025	0.171	0.045
	(0.052)	(0.770)	(0.053)
Any household shock in last 12 months	−0.205	−4.227	−0.102
	(0.339)	(3.420)	(0.345)
=1 if Muslim	0.153	−5.484	0.112
	(0.214)	(3.814)	(0.236)
=1 if unknown religion	1.168	7.702	0.925
	(1.968)	(4.737)	(1.802)
=1 if forward caste	−0.229	5.640*	−0.312
	(0.273)	(2.904)	(0.309)
=1 if minority backward caste	−0.037	−1.860	−0.010
	(0.419)	(2.973)	(0.450)
=1 if scheduled caste or tribe	−0.224	1.439	−0.317
	(0.240)	(2.420)	(0.246)
=1 if unknown caste	0.442	1.389	0.391
	(0.428)	(2.847)	(0.424)
Water and garbage disposal index	−0.160	16.853***	−0.445**
	(0.167)	(3.906)	(0.182)
F-statistic			12.90
Observations	891	863	863
Clusters	41	40	40
Adjusted R-squared	0.11	0.73	0.10

Sample: children aged 0–5.
Notes: Standard errors clustered at village level in parentheses. Significance: *10%, **5%, ***1%.

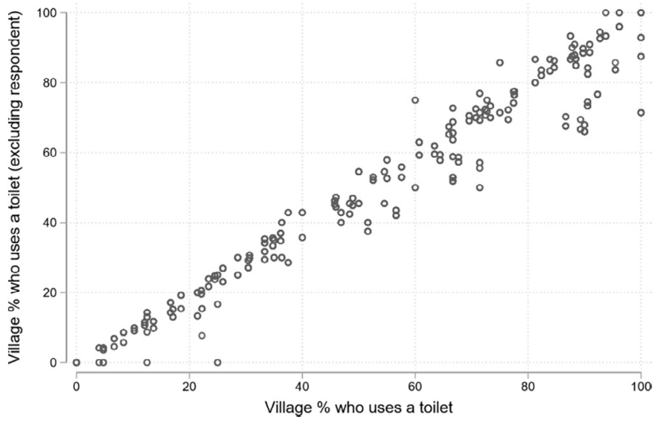

Fig. 8. Relationship between alternative definitions of sanitation environment.

A.6. Appendix Alternative definition of sanitation environment

One particular concern with our definition of ES_v, which applies to village v, is that it is positively correlated with household i 's usage of facilities S_{iv}. Hence, it is possible that for small villages ES_v is just a proxy of S_{iv}. In order to understand this problem, we present our main results under the following alternative definition of sanitation environment:

$$ES^{ex}_{iv} = \frac{\sum_{k \neq i}^{N_v} S_{iv}}{N_v - 1}. \quad (16)$$

This definition considers the average usage of the facilities of a village population but excluding the relevant household. As a result of this alternative definition, the correlation between ES_v and S_{iv} arises due to peer and contextual effects, rather than purely by construction. Fig. 8 shows that the measures are highly correlated (correlation coefficient of 0.983), which is mainly because of the size of the villages. In this figure, we observe that there are still noticeable differences: for instance, the most extreme case shows a village with coverage of 100% under the original ES_v definition which becomes 70% once the alternative ES^{ex}_{iv} is considered. While this is an extreme case, in general villages with the highest coverage levels are smaller and, as a result, the correlation between the measures becomes weaker. Tables 13 and 14 show that despite such differences, the results are almost the same in magnitude and significance. The difference in number of observations between the exercises is due to missing information on the household usage

Table 13
Sanitation environment and height-for-age – alternative definitions.

	$ES_v = \frac{1}{N_v}\sum_k^{N_v} S_{k,v}$		$ES^{ex}_{iv} = \frac{1}{N_v-1}\sum_{k\neq i}^{N_v} S_{k,v}$	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Panel A: second stage % of village that use a toilet	0.00378	0.01702**	0.00304	0.01740**
	(0.00459)	(0.00809)	(0.00482)	(0.00850)
Panel B: first stageSanitation raw materials price (1000 Rps)		−8.05712***		−7.78788***
		(2.24421)		(2.15938)
F-statistic		12.89		13.01
Observations	892	864	888	860
Clusters	41	40	41	40
Adjusted R-squared	0.1137	0.1021	0.1131	0.1023

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Controls: third-order polynomial in age, gender, main woman's education, main woman's age and height, quartiles of self-reported HH income and its mean, total consumption expenditures of HH in last year, quality of the dwelling, HH size, number of HH members who are male, any adverse shock in last 12 months, religion and caste dummies, living near Gwalior centre and round 2 dummies, and a factor for quality of water and garbage disposal. Standard errors clustered at village level in parentheses. Significance: *10%, **5%, ***1%.

Table 14
Sanitation environment and height-for-age – alternative definitions.

	(1)	(2)	(3)	(4)	(5)	(6)
		OLS			IV	
	Male	Female	Both	Male	Female	Both
Panel A: second stage% of village that use a toilet (excluding respondent)	−0.000	0.008		0.008	0.026***	
	(0.006)	(0.006)		(0.009)	(0.009)	
Village average × Boy			0.002			0.014
			(0.005)			(0.010)
Village average × Girl			0.004			0.022***
			(0.005)			(0.008)
Girl			−0.035			−0.247
			(0.206)			(0.300)
Panel B: first stage Sanitation raw materials price (1000 Rps)				−7.953***	−7.806***	
				(2.092)	(2.152)	
F-statistic				14.46	13.15	17.76 / 13.11
Observations	456	432	888	443	417	860
Clusters	40	40	41	39	39	40
Adjusted R-squared	0.07	0.15	0.11	0.07	0.12	0.10
p-value for H_0: $\beta_{Girls} - \beta_{Boys} = 0$			0.65			0.21

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Controls: third-order polynomial in age, gender, main woman's education, main woman's age and height, quartiles of self-reported HH income and its mean, total consumption expenditures of HH in last year, quality of the dwelling, HH size, number of HH members who are male, any adverse shock in last 12 months, religion and caste dummies, living near Gwalior centre and round 2 dummies, and a factor for quality of water and garbage disposal. Standard errors clustered at village level in parentheses. Significance: *10%, **5%, ***1%.

Table 15
Sanitation environment and height-for-age – usage definitions.

	Everybody uses		Someone uses		Ownership	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV
Panel A: second stage Sanitation coverage according to top row	0.00378	0.01702**	0.00355	0.01655**	0.00360	0.01997**
	(0.00459)	(0.00809)	(0.00437)	(0.00780)	(0.00495)	(0.01003)
Panel B: first stageSanitation raw materials price (1000 Rps)		−8.05712***		−8.28620***		−6.86723***
		(2.24421)		(2.27317)		(2.22668)
F-statistic		12.89		13.29		
Observations	892	864	892	864	892	864
Clusters	41	40	41	40	41	40
Adjusted R-squared	0.1137	0.1021	0.1135	0.1026	0.1134	0.0967

Notes: Own calculations based on FINISH sanitation household data for Gwalior and raw materials prices from Gautam (2016). Controls: third-order polynomial in age, gender, main woman's education, main woman's age and height, quartiles of self-reported HH income and its mean, total consumption expenditures of HH in last year, quality of the dwelling, HH size, number of HH members who are male, any adverse shock in last 12 months, religion and caste dummies, living near Gwalior centre and round 2 dummies, and a factor for quality of water and garbage disposal. Standard errors clustered at village level in parentheses. Significance: *10%, **5%, ***1%.

Table 16
Alternative definitions of toilet usage.

	Mean	SD
Panel A: round 1% of village that use a toilet (everyone in the HH)	44.53247	35.26733
% of village that use a toilet (someone in the HH)	44.59889	35.24336
% of village that own a toilet	41.69981	32.82545
N	38	
Panel B: round 2% of village that use a toilet (everyone in the HH)	56.62815	30.4355
% of village that use a toilet (someone in the HH)	57.30069	29.77932
% of village that own a toilet	58.98418	27.71415
N	43	

Standard deviations clustered at municipality level.

variable. The definition without the exclusion assumes that all households that do not report usage are non-users (116 cases out of 7,340). We decided to construct ES_{iv}^{ex} excluding missings as this would increase the difference between the two definitions. The fact that the results are solid even with different samples is reassuring not only about the underlying concept that is being considered, but also in testing that results are not driven by a particular set of observations.

A.7. Alternative definition of usage

In this exercise, we consider three alternative definitions of sanitation usage. The first is the standing definition in the main text: a household is classified as a 'user' if everybody in the household uses the dwelling's toilet or if household members are using public facilities. For the second definition, it is enough that someone in the household uses the dwelling's facilities. The third and last is the most restrictive definition, requiring toilet ownership at the dwelling and excluding the possibility of using other facilities. Results are presented in Table 15. The coefficients and standard errors obtained from these approaches show that the effect is almost the same regardless of the specification of usage. This is to be expected, as the three measures are very similar, as shown in Table 16.

References

Adair, L., Fall, C., Osmond, C., Stein, A., Martorell, R., Ramirez-Zea, M., & Victora, C. (2013). Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: Findings from five birth cohort studies. *The Lancet, 382*(9891), 525–534.

Almond, D., & Currie, J. (2011). Human capital development before age 5. In O. Ashenfelter & D. Card (Eds.), *Handbook of Labor Economics, 4B* (pp. 1315–1486). Amsterdam: Elsevier.

Andrés, L., Briceño, B., Chase, C., & Echenique, J. (2017). Sanitation and externalities: Evidence from early childhood health in rural India. *Journal of Water, Sanitation and Hygiene for Development, 7*(2), 272–289.

Angrist, J., & Pischke, J. (2008). *Mostly harmless econometrics: An empiricist's companion*. Princeton, NJ: Princeton University Press.

Ashraf, N., Berry, J., & Shapiro, J. M. (2010). Can higher prices stimulate product use? Evidence from a field experiment in Zambia. *American Economic Review, 100*(5), 2383–2413.

Attanasio, O., Cattan, S., Fitzsimons, E., Meghir C., Rubio-Codina M. (2015). Estimating the production function for human capital: results from a randomized control trial in Colombia. NBER Working Paper 20965.

Augsburg, B., Rodríguez-Lesmes, P., (2015) FINISH impact evaluation report. https://www.ifs.org.uk/publications/8857.

Barcellos, S. H., Carvalho, L. S., & Lleras-Muney, A. (2014). Child gender and parental investment in India: Are boys and girls treated differently? *American Economic Journal: Applied Economics, 6*(1), 157–189.

Basu, A. (1989). Is discrimination in food really necessary for explaining sex differentials in childhood mortality? *Population Studies, 43*, 193–210.

Behrman, J., Calderon, M., Preston, S., Hoddinott, J., Martorell, R., & Stein, A. (2009). Nutritional supplementation of girls influences the growth of their children: Prospective study in Guatemala. *American Journal of Clinical Nutrition, 90*(5), 1372–1379.

Bennett, D. (2012). Does clean water make you dirty? Water supply and sanitation in the Philippines. *Journal of Human Resources, 47*(1), 146–173.

BenYishay, A., A. Fraker, R. Guiteras, G. Palloni, N. Shah, S. Shirrell, ... (2016). Microcredit and willingness to pay for environmental quality: evidence from a randomized-controlled trial of finance for sanitation in rural Cambodia. Maryland Population Research Center, Working Paper 2016-003.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics, 119*(1), 249–275.

Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., de Onis, M., Ezzati, M., ... Rivera, J. (2008). Maternal and child undernutrition: Global and regional exposures and health consequences. *The Lancet, 371*(9608), 243–260.

Borooah, V. K. (2004). Gender bias among children in India in their diet and immunisation against disease. *Social Science & Medicine, 58*(9), 1719–1731.

Bozzoli, C., Deaton, A., & Quintana-Domeque, C. (2009). Adult height and childhood disease. *Demography, 46*(4), 647–669.

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

Cameron, A., Gelbach, J., & Miller, D. (2008). Bootstrap-based improvements for inference with clustered errors. *The Review of Economics and Statistics, 90*(3), 414–427.

Campbell, D., Elia, M., & Lunn, P. (2003). Growth faltering in rural Gambian infants is associated with impaired small intestinal barrier function, leading to endotoxemia and systemic inflammation. *Journal of Nutrition, 133*(5), 1332–1338.

Checkley, W., Buckley, G., Gilman, R., Assis, A., Guerrant, R., Morris, S., ... Black, R. (2008). Multi-country analysis of the effects of diarrhoea on childhood stunting. *International Journal of Epidemiology, 37*(4), 816–830.

Clasen, T., Boisson, S., Routray, P., Torondel, B., Bell, M., Cumming, O., ... Schmidt, W.-P. (2014). Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: A cluster-randomised trial. *The Lancet Global Health, 2*(11), e645–e653.

Coffey, D. (2014). Sanitation externalities, disease, and children's anemia. Working Paper presented at 2014 Annual Meeting of Population Association of America, Princeton University, r.i.c.e.

Cohen, J., & Dupas, P. (2010). Free distribution or cost-sharing? Evidence from a randomized malaria prevention experiment. *Quarterly Journal of Economics, 125*(1), 1–10.
Cumming, O., & Cairncross, S. (2016). Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Maternal & Child Nutrition, 12*(S1), 91–105.
Currie, J. (2000). Child health in developed countries. In A. J. Culyer & J. P. Newhouse (Eds.), *Handbook of health economics, 1B* (pp. 1053–1090). Amsterdam: Elsevier.
Das Gupta, M. (1987). Selective discrimination against female children in rural Punjab India. *Population and Development Review, 13*(1), 77–100.
Davidson, R., & MacKinnon, J. G. (2010). Wild bootstrap tests for IV regression. *Journal of Business and Economic Statistics, 28*(1), 128–144. Revised working paper version 2013.
M. de Onis D. Brown M. Blossner E. Borghi 2015 Levels and trends in child malnutrition UNICEF–WHO–The World Bank joint child malnutrition estimates
Deaton, A. (2007). Height, health, and development. *Proceedings of the National Academy of Sciences, 104*(33), 13232–13237.
Dickinson, K. L., Patil, S. R., Pattanayak, S. K., Poulos, C., & Yang, J.-H. (2015). Nature's call: Impacts of sanitation choices in Orissa India. *Economic Development and Cultural Change, 64*(1), 1–29.
Duflo, E., Greenstone, M., Guiteras, R., Clasen T. (2015). Toilets can work: short and medium run health impacts of addressing complementarities and externalities in water and sanitation. NBER Working Paper 21521.
Dupas, P. (2009). What matters (and what does not) in households' decision to invest in malaria prevention? *American Economic Review, 99*(2), 224–230.
FINISH (2012). Finish programme annual report 2011–2012 Available at http://finishsociety.org/annual_report.html.
Fuller, J., 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.
Ganatra, B., & Hirve, S. (1994). Male bias in health care utilization for under-fives in a rural community in western India. *World Health Organization Bulletin, 72*(1), 101–104.
Gautam, S. (2016). Quantifying welfare effects in the presence of externalities: An ex-ante evaluation of a sanitation intervention. Unpublished.
Gertler, P., Shah, M., Alzua, M., Cameron, L., Martinez, S., Patil S. (2015). How does health promotion work? Evidence from the dirty business of eliminating open defecation. NBER Working Paper 20997.
Geruso, M., Spears, D. (2014). Sanitation and health externalities: resolving the Muslim mortality paradox. University of Texas at Austin Working Paper.
Ginsburg, E., Livshits, G., Yakovenko, K., & Kobyliansky, E. (1998). Major gene control of human body height, weight and BMI in five ethnically different populations. *Annals of Human Genetics, 62*(4), 307–322.
Godfrey, A. (2008). Situation assessment of the supply market for rural sanitation in Himachal Pradesh and Madhya Pradesh. Report 72448. Water and Sanitation Program of the World Bank.
Grantham-McGregor, S., Cheung, Y., Glewwe, P., Richter, L., & Strupp, B. (2007). Developmental potential in the first 5 years for children in developing countries. *The Lancet, 369*(9555), 60–70.
Guiteras, R., Levinsohn, J., & Mobarak, A. M. (2015). Encouraging sanitation investment in the developing world: A cluster-randomized trial. *Science, 348*(6237), 903–906.
Hammer, J., Spears D. (2013). Village sanitation and children's human capital: evidence from a randomized experiment by the Maharashtra government. World Bank Policy Research Working Paper 6580.
Hathi, P., Haque, S., Pant, L., Coffey, D., Spears, D. (2014). Place and child health: the interaction between density and sanitation in developing countries. World Bank Policy Research Working Paper 7124.
Hathi, P., Haque, S., Pant, L., Coffey, D., & Spears, D. (2017). Place and child health: The interaction of population density and sanitation in developing countries. *Demography, 54*(1), 337–360.
Heckman, J.J., Macurdy, T.E., (1986). Chapter 32 labor econometrics. in: Griliches, Z., Intriligator, M. (Eds.) Handbook of Econometrics, Vol. 3, pp. 1917–1977. Elsevier.
Hoddinott, J., Behrman, J., Maluccio, J., Melgar, P., Quisumbing, A., Ramirez-Zea, M., ... Martorell, R. (2013). Adult consequences of growth failure in early childhood. *The American Journal of Clinical Nutrition, 98*(5), 1170–1178.
Hoddinott, J. F., Maluccio, J. A., Behrman, J. R., Flores, R., & Martorell, R. (2008). Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. *The Lancet, 371*(9610), 411–416.
Jayachandran, S., & Kuziemko, I. (2015). Why do mothers breastfeed girls less than boys? Evidence and implications for child health in India. *Quarterly Journal of Economics, 126*(3), 1485–1538.
Kumar, N., & Aggarwal, S. (2008). Level of poverty and employment pattern in slums: A case of Gwalior in central India. *The Indian Journal of Labour Economics, 51*(2), 323–338.
Kumar, S., & Vollmer, S. (2013). Does access to improved sanitation reduce childhood diarrhoea in rural India? *Health Economics, 22*(4), 410–427.
Lin, A., Arnold, B., Afreen, S., Goto, R., Nurul Huda, T., Haque, R., ... Luby, S. (2013). Household environmental conditions are associated with enteropathy and impaired growth in rural Bangladesh. *American Journal of Tropical Medicine and Hygiene, 89*(1), 130–137.
Lunn, P., Northrop-Clewes, C., & Downes, R. (1991). Intestinal permeability, mucosal injury, and growth faltering in Gambian infants. *The Lancet, 338*(8772), 907–910.
MacKinnon, J.G., Webb, M.D.(2016). Wild bootstrap inference for wildly different cluster sizes. Queen's University Economics Department Working Paper 1314.
Maluccio, J. A., Hoddinott, J. F., Behrman, J. R., Quisumbing, A. R., Martorell, R., & Stein, A. D. (2009). The impact of nutrition during early childhood on education among Guatemalan adults. *Economic Journal, 119*(537), 734–763.
Mbuya, M., & 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.
Merchant, A., Jones, C., Kiure, A., Kupka, R., Fitzmaurice, G., Herrera, M., & Fawzi, W. (2003). Water and sanitation associated with improved child growth. *European Journal of Clinical Nutrition, 57*(12), 1562–1568.
Mosley, W., & Chen, L. (1984). An analytical framework for the study of child survival in developing countries. *Bulletin of the World Health Organization, 81*(2), 140–145.
Nokes, C., Grantham-McGregor, S., Sawyer, A., Cooper, E., Robinson, B., & Bundy, D. (1992). Moderate-to-heavy infections of *Trichuris trichiura* affect cognitive function in Jamaican school children. *Parasitology, 104*(3), 539–547.
Nokes, C., van den Bosch, C., & Bundy, D. (1998). *The effects of iron deficiency and anemia on mental and motor performance, educational achievement, and behavior in children: A report of the international nutritional anemia consultative group*. Washington DC: USAID.
NSSO (2010). Some characteristics of urban slums 2008–09. Report 534. National Sample Survey Office, National Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India.
Ozler, B. (2012). Beware of studies with a small number of clusters. Blog, June.
Pande, R. P., & Astone, N. M. (2007). Explaining son preference in rural India: The independent role of structural versus individual factors. *Population Research and Policy Review, 26*(1), 1–29.
Patil, R., Arnold, B., Salvatore, A., Briceño, B., Ganguly, S., Colford, J., Jr, & Gertler, P. (2014). The effect of India's total sanitation campaign on defecation behaviors and child health in rural Madhya Pradesh: A cluster randomized controlled trial. *PLoS Med, 11*(8). https://doi.org/10.1371/journal.pmed.1001709.
Pattanayak, S.K., Dickinson, K. L., Yang, J-C., Patil, S. R., Praharaj P., Poulos C. (2007). Promoting latrine use: midline findings from a randomized evaluation of a community mobilization campaign in Bhadrak, Orissa. Research Triangle Institute Working Paper 2.
Pickering, A., Djebbari, H., Lopez, C., Coulibaly, M., & Alzua, M. (2015). Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: a cluster-randomised controlled trial. *The Lancet, 3*(11), 701–711. Puentes.
Pruess-Uestuen, A., Bos, R., Gore, F., & Bartram, J. (2008). *Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health*. World Health Organization.
Puentes, E., Wang, F., Behrman, J., Cunha, F., Hoddinott, J., Maluccio, J., ... Stein, A. (2016). Early life height and weight production functions with endogenous energy and protein inputs. *Economics & Human Biology, 22*, 65–81.
Richard, S., Black, R., Gilman, R., Guerrant, R., Kang, G., Lanata, C., ... Checkley, W. (2013). Diarrhea in early childhood: Short-term association with weight and long-term association with length. *American Journal of Epidemiology, 178*(7), 1129–1138.
Silventoinen, K. (2003). Determinants of variation in adult body height. *Journal of Biosocial Science, 35*(2), 263–285.
Smith, L., & Haddad, L. (2015). Reducing child undernutrition: Past drivers and priorities for the post-MDG era. *World Development, 68*, 180–204.
Spears, D. (2011). Economic decision-making in poverty depletes behavioral control. *BE Journal of Economic Analysis and Policy, 11*(1).
Spears, D. (2012). Effects of rural sanitation on infant mortality and human capital: evidence from India's Total Sanitation campaign. Princeton University Working Paper.
Spears, D. (2014). Increasing average exposure to open defecation in India, 2001–2011. r.i.c.e. Working Paper.
Spears, D., & Lamba, S. (2016). Effects of early-life exposure to rural sanitation on childhood cognitive skills: Evidence from India's Total Sanitation campaign. *Journal of Human Resources*. https://doi.org/10.3368/jhr.51.2.0712-5051R1.
Staiger, D., & Stock, J. H. (1997). Instrumental variables regression with weak instruments. *Econometrica, 65*(3), 557–586.
Todd, P., & Wolpin, K. (2003). On the specification and estimation of the production function for cognitive achievement. *The Economic Journal, 113*(485), F3–F33.
UN-Habitat (2010). State of the world's cities 2010/2011 report: bridging the urban divide. UN-Habitat (United Nations Human Settlements Programme).
VanDerslice, J., Popkin, B., & Briscoe, J. (1994). Drinking-water quality, sanitation, and breast-feeding: Their interactive effects on infant health. *Bulletin of the World Health Organization, 72*(4), 589–601.
Victora, C., de Onis, M., Hallal, P., Bloessner, M., & Shrimpton, R. (2010). Worldwide timing of growth faltering: Revisiting implications for interventions. *Pediatrics, 125*(3), e473–e480.
Vyas, S., Gupta, A. Medeazza, G., Spears D. (2014). Open defecation, population density, and child height in Madhya Pradesh, India: an ecological analysis of new data on 22,000 children. r.i.c.e. Working Paper.
Walker, S. P., Wachs, T. D., Grantham-McGregor, S., Black, M. M., Nelson, C. A., Huffman, S. L., ... Richter, L. (2011). Inequality in early childhood: Risk and protective factors for early child development. *The Lancet, 378*(9799), 1325–1338.
WHO (2008). Poor sanitation threatens public health. News Release. March.
WHO (2013). Diarrhoeal disease. Fact Sheet 330. April.