Nature's Call: Impacts of Sanitation Choices in Orissa, India

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I. Introduction

About half of the world's population lacks access to basic sanitation facilities (Watkins 2006; UNICEF/WHO 2012). Lacking toilets, billions of people across the world respond to nature's call in fields, ditches, rivers, and roadsides—a practice called "open defecation," which potentially is a major contributor to the global burden of diseases (Prüss-Üstün and Corvalán 2006; Prüss-Üstün et al. 2008). Although there has been growing attention to sanitation within public health and development communities (2008 was the International Year of Sanitation), there is little careful empirical research on this subject. Recent meta-analyses and reviews by Fewtrell et al. (2005), Clasen et al.

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(2007), Zwane and Kremer (2007), Waddington et al. (2009), Cairncross et al. (2010), and Norman, Pedley, and Takkouche (2010) have been able to identify only a few studies that examine the health effects of sanitation in underdeveloped tropical countries. Unfortunately, the existing evidence base (e.g., Daniels et al. 1990; Esrey 1996; Lee, Rosenzweig, and Pitt 1997; Cheung 1999; Kumar and Vollmer 2013) does not provide rigorous impact estimates because these studies lack some combination of credible control groups, robust research designs, or large samples.

The knowledge gap is of particular concern because governments and public health practitioners are struggling to plan and implement large-scale programs and policies to respond to this critical problem, particularly in sanitation hot spots such as India. Although much of the developing world lacks basic sanitation, open defecation is concentrated in South Asia. In India alone, over 650 million people (58% of the country's population) lack access to even the most basic sanitation facilities. Sanitation conditions also vary substantially within India. The prevalence of open defecation in urban areas was only 18% in 2006, compared to a startling 74% in rural areas (WHO/UNICEF 2008). In the state of Orissa, where our empirical study took place, only about 10% of rural households had access to a toilet facility in 2007 (Government of India 2007).

At a national scale, India established the Central Rural Sanitation Program in 1986 (DDWS 2007). However, as in other parts of the developing world until relatively recently, sanitation tended to take a backseat to other antidiarrheal policies such as water quality and quantity interventions and disease-treatment policies like case management, rapid testing, care seeking, and the development and diffusion of vaccines (Cairncross and Valdmanis 2006; Keusch et al. 2006; Bartram and Cairncross 2010; Mara et al. 2010). Furthermore, early attempts to address the sanitation challenge tackled the problem from a supply-side engineering perspective—building latrines—only to find that many households failed to use and maintain these facilities (Kar 2003; Chambers 2009; Pattanayak et al. 2009). In response to a growing recognition that effective policies would need to address demand for sanitation as well as its supply, India restructured its efforts and launched the Total Sanitation Campaign in 1999. This new approach was intended "to increase awareness among the rural people and [generate] demand for sanitary facilities" (DDWS 2007, 2).

Experts working on demand-side approaches disagree over the relative merits of an economic subsidy (recognizing seriousness of income constraints) versus more behavioral and social marketing based "shaming" approaches that rely on intrinsic motivation and emotional triggers (shame, shock, disgust). The Community-Led Total Sanitation (CLTS) strategy speaks directly to this debate. Originally developed and implemented in Bangladesh, this method focused on “empowering local people to analyze the extent and risk of environmental pollution caused by open defecation” (Kar 2003, iii). CLTS has expanded slowly from Bangladesh to India, Indonesia, and other parts of South Asia, East Asia, Pacific regions, and eastern and southern Africa—reaching more than 20 million people in 44 countries (Sanan and Moulik 2007; Kar 2011). Yet, rigorous analyses of its impacts are nonexistent.

Our article responds directly to the need for careful evaluation of the impacts of a promising public health policy in the developing world (Pattanayak 2009). As described in Sections II and III, we draw on a randomized community-led sanitation campaign in Orissa, India, to study the impacts of households’ transition from open defecation to use of latrines. Thus, we contribute to a small but growing body of knowledge on the links between sanitation, health, and welfare (e.g., Altaf and Hughes 1994; Persson 2002; Whittington et al. 2008; Fink, Günther, and Hill 2011; Bennett 2012).

In Section IV, we show that self-reported diarrhea rates decreased after improvements in community sanitation, although these effects are not statistically significant at conventional levels. Stronger evidence in support of health impacts comes from our analyses of more stable and continuous measures of nutritional status: we find statistically and substantively significant improvements in mid-upper-arm circumference, height, and weight as a result of the sanitation campaign and associated latrine use. Thus, our results indicate that increased latrine use improved health outcomes for children in our study area.

We also observe sizable nonhealth benefits for households that adopted latrines: they saved time (from avoiding walking long distances to defecation sites) and were more satisfied with their sanitation conditions. Thus in Section V, we conclude by discussing the policy implications of our findings regarding household choices and net benefits.

II. Simple Analytics of Sanitation: Framework and Study Design

The demand for toilets can be viewed as a special case of utility maximization theory—the household production model as applied to environmental health (Pattanayak and Pfaff 2009). Under this stylized description, households “produce” utility-yielding services such as health by combining their labor, money, capital, and environmental inputs. A typical household maximizes utility by consuming leisure, health, and a composite consumption good. Utility is maximized subject to a budget constraint (expenditures on consumption items and household production inputs must be no greater than the sum of exogenous and earned income). In addition, households face a second constraint that is dictated by the health production function, which describes the relationship between health and environmental inputs (e.g., community water quality and quantity). These environmental inputs, in turn, depend on public policies (such as the expansion of infrastructure networks and hygiene education campaigns), individual actions (e.g., point-of-use water treatment), and aggregate community-level behaviors (e.g., proportion of village members practicing open defecation).

How does this stylized framework help us understand why rural Oriya households were initially reluctant to build toilets and needed a nudge? First, if the end goal is improving health through improved environmental quality, sanitation is one (potentially key) among many pathways toward that goal. Other pathways toward reduced exposure to environmental pathogens include water source improvement (Kremer et al. 2011) and better in-home water handling (Hamoudi et al. 2012; Jeuland et al. 2015). Furthermore, the relationships among these various inputs and their relative contributions to health production are complex and contextually dependent. For example, households might substitute water quality (piped water) for sanitation (Bennett 2012). Thus, a priori better sanitation may not improve health. Second, households in our settings typically face serious liquidity and credit constraints, in addition to heavily discounting the future, leading to high up-front costs mattering more than distant uncertain benefits. Finally, a typical household will not consider the positive externalities of improving local water quality, which leads to socially suboptimal levels of individual latrine adoption.

Consider at least two potential fixes to this conundrum of insufficient latrine demand. To begin with, a closer examination of the reality on the ground leads us to amend the basic model to allow latrines also to contribute directly to household utility (i.e., not exclusively through the health pathway). For example, women benefit from the privacy, security, and convenience afforded by latrines, instead of having to wake up early in the morning and always walk and defecate in the company of other women.[1] In our study, time savings emerge as an important "cobenefit" of latrine adoption because individuals avoid long walks to defecation sites. The presence of such tangible, private benefits may increase adoption levels compared to the case of a purely public good.[2] Critically, a second way to increase latrine adoption is through inter-

[1] For example, in rural Benin, latrines were built to satisfy "prestige" and "well-being" goals such as identifying with the elite or increasing convenience and comfort, which played a more important role than avoidance of fecal-oral disease transmission per se (Jenkins and Curtis 2005).

[2] More accurately, because latrines generate private benefits (times savings, privacy) and contribute to the public good of clean water, latrines are impure public good (Cornes and Sandler 1984, 1994; Vicary 1997). Thus, increasing the actual or perceived private benefits of latrines may reduce free riding and increase public good provision.

ventions of various kinds that either decrease the costs or increase the perceived benefits of latrine adoption. Specifically, demand for latrines will expand if (1) time, knowledge, or materials are subsidized, especially to reduce the up-front fixed costs; (2) technical know-how is enhanced to improve the quality of latrines; (3) nonhealth aspects of latrines such as dignity, privacy, and security are clarified; (4) private health benefits and external benefits (via water quality) of latrines are clarified and appreciated; or (5) social norms shift in favor of latrine use. The CLTS campaign triggered several of these levers in our study setting. Our article focuses on the nature and magnitude of the CLTS impacts.

Study Site and Design

To provide a high-quality evaluation of the effects of a CLTS-inspired intervention on sanitation and related health and welfare outcomes, we conducted a randomized intervention in Bhadrak district, Orissa, between 2005 and 2006. Within Orissa, we chose this district as our study area for three reasons. First, Bhadrak still had a sufficiently large number of blocks and villages where the government of India's existing Total Sanitation Campaign interventions had not been implemented. Second, the use and maintenance of latrines in the area remained unsatisfactory despite adequate water availability, and third, the Government of Orissa agreed that no special water, sanitation, or hygiene programs would be implemented in control villages during the study period.

Out of about 1,200 total villages in Bhadrak district, we selected 40 study villages using the following criteria. First, we limited our study to two adjacent blocks, Tihidi and Chandbali, that were accessible by road. Next, we excluded villages with less than 70 or more than 500 households, to ensure that included villages would be similarly rural and would provide enough households with at least one child under age 5, since the main health outcomes we are measuring include child diarrhea rates and anthropometry. Finally, to minimize spillover effects, we randomly selected one village per panchayat, mapped the remaining villages, and removed villages that were adjacent to one another.[3] That is, our study design took care to ensure that the distance between villages included in the study was great enough that sanitation improvements in one village would not result in health gains in other study villages.

In order to assess the impact of the sanitation intervention on household sanitation behaviors, child health outcomes, and welfare measures, we implemented a repeated-measures cohort design. In August 2005, enumerators listed

[3] Gram panchayat is the lowest-level administrative unit in India consisting of a cluster of three to six villages.

and mapped eligible households in each village (i.e., households with at least one child under 5) and then randomly selected 28 households from each villages and collected baseline data using a household survey. Subsequently, in a town hall–style gathering of village leaders, we randomly selected 20 of the 40 sample villages from a bucket containing slips of paper with village names. These 20 villages were assigned to the "treatment" group, while the other 20 villages served as "controls." Between March and May 2006, the intervention took place in the 20 treatment villages, and postintervention data were collected from the same set of households in August and September 2006. The 2005 baseline survey covered 1,086 households (treatment = 534, control = 552), and 1,050 of these (treatment = 529, control = 521) completed follow-up surveys in 2006; our analyses in this article use data from that panel of 1,050 households with completed surveys in both years.[4] Within those households, health outcomes were collected for all children under 5 in each year: in 2005, there were 1,572 children (797 treatment, 775 control), while in 2006 there are 1,256 children (641 treatment, 615 control). Attrition in 2006 is due mainly to children who turned 5 between 2005 and 2006. Our data were collected by approximately 30 local enumerators employed by TNS, an international survey organization. Surveys were conducted in the local language (Oriya). The study protocol was approved by an ethics review board, an external technical oversight group from leading public health agencies, and a state government steering committee. Throughout the design stage of this study, the evaluation team worked closely with the government of Orissa as well as the sanitation campaign implementation team to ensure consistency and coherence across all aspects of the study, including integrity of the design and measurement.

Table 1 presents descriptive statistics for a number of household and village characteristics in 2005 (before the intervention). For each characteristic, we present *p*-values for the null hypotheses that means are equal across the treatment and control villages. In addition, in this set of tests and throughout the article, we present an alternate "*q*-value" that accounts for the fact that multiple hypotheses are being tested simultaneously and controls the false discovery rate

[4] Power calculations performed during the study design phase used the following parameters and assumptions: type I error rate = 0.10, type II error rate = 0.20, baseline diarrhea prevalence = 30% (IIPS and ORC Macro 2000), estimated effect size = 30% (Fewtrell et al. 2005), intracluster correlation coefficient = 0.05 (Katz et al. 1993), and two-tailed test. Based on these inputs, our power calculation indicated that a sample of 1,000 households with children under 5 (25 households in each of the 40 villages) would be sufficient to detect the impact of latrines on diarrhea.

TABLE 1

COMPARISON OF MEANS FOR VILLAGE CHARACTERISTICS IN 2005 (PREINTERVENTION)

Variable	Overall		Treatment		Control		Treatment − Control		Unadjusted *p*-value	FDR-adjusted *q*-value
Village population density (people/acre)	21	(5.3)	13	(4.8)	30	(9.2)	−17	(10.4)	.11	.37
Distance from all-weather road (minutes by foot)	45	(4.9)	50	(6.7)	41	(7.3)	9.2	(9.9)	.36	.69
% open caste	43	(3.7)	40	(5.5)	46	(5.1)	−5.5	(7.5)	.47	.72
% primary caregivers with primary education	20	(1.2)	20	(1.5)	19	(1.9)	.6	(2.4)	.80	.94
% primary caregivers with secondary+ education	53	(1.7)	53	(2.6)	53	(2.3)	.04	(3.5)	.99	.99
Average expenditure in past 30 days (Rs)	2,463	(97)	2,337	(139)	2,589	(134)	−251	(193)	.20	.44
% owning land	85	(1.8)	87	(2.8)	84	(2.3)	2.7	(3.7)	.43	.72
% owning TV	13	(2.0)	8.3	(2.1)	17	(3.2)	−8.5	(3.9)	.03**	.15
Handwashing frequency for mothers (out of 12)	6.3	(.24)	6.4	(.36)	6.2	(.32)	.18	(.48)	.71	.89
% HH using improved water source	41	(4.2)	38	(6.0)	43	(6.1)	−4.7	(8.6)	.57	.76
% HH treating drinking water	11	(1.5)	9.1	(1.8)	13	(2.5)	−4.3	(3.0)	.15	.43
% owning latrine	10	(2.0)	6.6	(1.6)	14	(3.6)	−7.5	(3.9)	.07*	.28
% children under 5 having diarrhea in past 2 weeks	25	(1.8)	28	(3.1)	23	(1.8)	5.0	(3.6)	.18	.44
Mid-upper-arm circumference-for-age *z*-score (children <5)	−1.40	(.037)	−1.43	(.052)	−1.36	(.051)	−.065	(.073)	.38	.69
Height-for-age *z*-score for children under 5	−2.15	(.059)	−2.16	(.086)	−2.14	(.084)	−.020	(.12)	.87	.94
Weight-for-age *z*-score for children under 5	−2.18	(.63)	−2.14	(.086)	−2.22	(.095)	.08	(.13)	.52	.74
Time spent walking to defecation site:										
Men	11	(.57)	13	(.84)	9.9	(.69)	2.6	(1.1)	.02**	.15
Women	11	(.56)	12	(.79)	9.6	(.68)	2.6	(1.0)	.02**	.15
Children	4.9	(.35)	4.9	(.54)	4.8	(.49)	.11	(.73)	.89	.94
Satisfaction with sanitation (4-point scale: 1 = completely dissatisfied, 4 = very satisfied)	1.63	(.058)	1.51	(.083)	1.75	(.073)	−.24	(.11)	.03**	.15

Note. Standard errors in parentheses; *p*-values from *t*-tests of differences between village-level means assuming unequal variances. Sample sizes: villages, 20 treatment, 20 control; households (HH), 534 treatment, 552 control. Hotelling T^2 test: H0, vectors of means are equal for treatment and control groups (*F*-statistic = 1.11, *p*-value = .41). FDR = false discovery rate.

* Significant at 10%.

** Significant at 5%.

(FDR; i.e., the proportion of falsely rejected true null hypotheses within a group of tests; Benjamini and Hochberg 1995).[5] This q-value can be interpreted as an "FDR-adjusted" p-value: that is, an alternative measure of the probability that a difference observed in the data is due to chance rather than an actual difference in means across the two groups of villages.

In general, treatment and control villages are similar, with few significant differences in observable covariates before the sanitation intervention. Qualitatively, treatment villages appear to be slightly worse off initially in terms of a few indicators—treatment villages had somewhat lower levels of population density and of TVs and, most notably, latrines in 2005. Adults in these households also reported spending more time walking to defecation sites and expressed lower levels of satisfaction with their sanitation conditions. However, none of the differences is significant once the FDR correction is applied, and a Hotelling T^2 test shows that, as a group, these variables are not significantly different across treatment and control groups.[6] Moreover, the inclusion of household covariates allows us to control for any observable confounders, beyond the balance achieved through randomization, in subsequent estimation of the intervention effects (tables 2 and 3).

The Sanitation Promotion Intervention

Inspired by the CLTS model (Chambers 2009; Kar 2011), the intervention that was implemented in Bhadrak focused squarely on the concept that targeting entire communities for behavior change is more effective than trying to encourage latrine use on a house-by-house basis (Pattanayak and Pfaff 2009). This approach is motivated in part by an understanding of the transmission

[5] The basic FDR procedure is as follows. For each family of outcomes (e.g., health, welfare), we test a set of hypotheses. If there are m outcomes in the family, we are testing m hypotheses for each model. We run these models normally and compute the associated p-values for each outcome i and then order those p-values from smallest to largest: $p(1) \leq p(2) \leq \ldots \leq p(m)$. Define q^* to be the desired FDR. We set this to 0.05. For each i, we examine whether $p(i) \leq (i/m) \times q^*$. If this condition holds, we reject hypotheses 1 through i. The q-value is defined as the smallest value that can be plugged in for q^* in the equation above that would result in the null hypothesis being rejected for a given $p(i)$.

[6] Further investigation revealed that a large portion of the apparent pretreatment differences could be explained by two control villages that were located close to the main highway and had higher rates of latrine ownership due to a previous government campaign, despite our attempts to exclude such villages from our initial sample frame. All analyses reported in this article were repeated in samples excluding these villages; results show pretreatment balance across treatment and control groups and no meaningful effect on conclusions regarding overall impact. Because all results are robust to inclusion of the full set of control villages, we report these more inclusive results in this article.

pathways for diarrhea and the ways in which sanitation improvements affect these pathways. In particular, sanitation practices in a community affect the overall environmental burden of fecal and associated parasites. These parasites are then transmitted through human consumption of drinking water and food and exposure to flies, affecting health outcomes. By appropriately disposing of feces through latrine use, the level of fecal matter in a community is reduced. Crucially, then, the *collective* level of sanitation in a community is a key determinant of individual health outcomes (Alderman, Hentschel, and Sabates 2003; Pattanayak and Pfaff 2009).

The Bhadrak sanitation campaign promoted community-wide latrine adoption (i.e., an end to open defecation) in the 20 randomly selected treatment villages through a number of participatory activities or components. The purpose of these activities was to create a sense of disgust and shame about open defecation and a desire for an immediate village-wide end to open defecation (Kar 2003). The "Walk of Shame" component consisted of a march through the village during which campaign motivators pointed out areas where people had openly defecated. The "Fecal Calculation" component had participants estimate the volume of feces generated by the village over a given period of time. Similarly, the "Spatial Mapping" activity had participants examine the spatial distribution of houses, open defecation hot spots, and drinking water sources to understand community exposure. These activities were meant to call attention to the level of contamination in the village and the collective nature of the problem: unless everyone stopped open defecation by using latrines, everyone would continue to be exposed to fecal matter. The goal was to induce entire villages to commit to becoming "open defecation free" by a collectively agreed-on date.

While the overarching philosophy of the campaign focused on community-level outcomes, campaign organizers also recognized that inducing households to change their behaviors required both reducing costs and increasing perceived benefits of latrine use. On the cost side, the campaign subsidized materials and labor for latrine construction for households eligible for government of India subsidies (i.e., below poverty line, or BPL, households). The typical construction cost for the offset pit latrine promoted under this campaign was Rs 1,500 (about US$30), of which BPL households were only required to pay Rs 300 (about US$6). These subsidies were intended to relax the budget constraint and reduce up-front fixed costs faced by poorer households. Furthermore, the campaign reduced costs of searching for information, by providing technical know-how and bringing skilled masons to guide household latrine building. The supply of both materials and expertise was increased through "sanitation marts" (production centers) that were operated by local nongovernmental organizations in each village.

On the benefit side, campaign activities emphasized the links between sanitation and health outcomes. In addition, the campaign placed much emphasis on the nonhealth benefits of latrine use. In particular, messages about latrines' convenience highlighted the potential time savings households could enjoy from changing their sanitation behaviors: open defecation generally requires walking to specific areas (fields, ditches, rivers, forests, etc.). Other less tangible benefits like privacy and dignity, particularly for women, also played a prominent role in the campaign's messages. By highlighting the downside of open defecation—including health and nonhealth factors—and promoting latrines as a solution to these problems, the primary goal of CLTS is to create an overwhelming sense of dissatisfaction that would spur widespread behavior change. In sum, the intervention influences many key elements of the costs and benefits to households, summarized in the conceptual framework, to spur demand for latrines.

After the campaign, the proportion of households owning latrines increased in treatment villages from about 7% to 35%, while latrine ownership in control villages was unchanged at about 15%. A difference-in-difference estimate indicates that the intervention increased latrine ownership by 27 percentage points. At the household level, the main variable explaining differences in adoption rates was BPL status, which determined eligibility for subsidies (Pattanayak et al. 2009). Latrine ownership increased by about 35 percentage points in BPL households, compared to roughly 20 percentage points in non-BPL households. In the next section, we examine how these changes in community-wide sanitation levels affected health and welfare.

III. Method for Measuring Health and Welfare Impacts

To measure the impacts of the Bhadrak campaign and resulting sanitation improvements, we focus on two sets of indicators: (1) child health and (2) sanitation-related welfare. Descriptive statistics for these different indicators at baseline, by treatment and control groups, are presented in table 1.

We measured child health impacts in terms of diarrhea prevalence and nutritional status. Diarrheal diseases are a major cause of death among children under 5; Prüss-Üstün and Corvalán (2006) estimate that about 1.5 million child deaths per year can be linked to water, sanitation, and hygiene. We collected data from primary caregivers on whether each child under 5 suffered from diarrhea in the 2 weeks before the survey. Analysis of this indicator allows us to compare our findings to other studies using the nearly universal

2-week indicator, which is common to almost all data sets collected by the Demographic and Health Surveys (DHS) from around the developing world (Fink et al. 2011).

Reductions in diarrheal disease burden are expected to decrease mortality as well as morbidity in affected populations. While our study was underpowered to measure changes in mortality, anthropometric measurements allowed us to gauge morbidity by assessing changes in children's height, weight, and mid-upper-arm circumference (MUAC)—all in *z*-scores to compare individual-level indicators to international age- and gender-specific growth standards. Height for age *z*-scores (HAZ) and weight for age *z*-scores (WAZ) are conventional nutritional indicators, viewed as proxies for stunting and wasting. Some contend that MUAC is the preferred indicator because it gauges both fat reserves and muscle mass and (unlike height) can decrease as well as increase in response to nutritional shocks (Alderman 2000). Low MUAC for age has been shown to predict subsequent child mortality (Vella et al. 1993).

We computed *z*-scores by comparing observed values for each child with published World Health Organization (WHO) standard growth benchmarks for males and females of different ages (WHO 2007).[7] For example, MUAC distributions tend to be skewed to the right, so that *z*-scores must be calculated using the LMS method (WHO 2007). In this case, we computed

$$z\_\text{arm}_{it} = \frac{(\text{arm}_{it}/M)^L - 1}{S \times L},$$

where M, S, and L are the age- and gender-specific median, generalized coefficient of variation, and the power in the Box-Cox transformation, respectively. As recommended by the WHO, there is a slight adjustment for observed *z*-scores beyond ±3 standard deviations (WHO 2007).

Finally, we also examined sanitation-related welfare indicators. While health impacts may motivate efforts to improve sanitation from a public health perspective, latrines may also have a range of more immediate, tangible costs and benefits for individual households (Pattanayak and Pfaff 2009; Pattanayak et al. 2010). These impacts could explain why households may (or may not) adopt latrines in a given setting (Bartram and Cairncross 2010; Mara et al. 2010). Thus, we analyzed time spent walking to defecation sites for adult

[7] For children less than 1 year, age was reported in months because it is more accurate to recollect recent births, whereas for older children >1 year, age was reported in years. While this introduces measurement error for the older children, it is of a classical nature that will cause attenuation bias; this measurement error is not systematically related to treatment assignment and therefore our final inference.

household members and households' subjective level of satisfaction with their sanitation situation. Walking time was measured using a multipart question that first asked households to indicate whether any household members used different methods (open defecation, private latrines, community toilets, neighbors' toilets) for defecation. Follow-up questions for households that reported open defecation collected more detailed information on defecation sites, including types of sites (fields, ditches, rivers) and the time it took to walk one way to each of the sites mentioned. For our outcome variable, we used reported walking times for men, women, and children.[8] We also analyzed responses to the question, "Overall, how satisfied are you with your main sanitation facilities?" measured on a 4-point scale from "completely dissatisfied" to "very satisfied."

To estimate the impact of the sanitation campaign in Bhadrak on each of the outcomes outlined above, we compared posttreatment (2006) differences across treatment and control groups:

$$Y_{i2006} = \beta_1 \text{Treatment}_i + \beta_2 X_i + \varepsilon_i, \qquad (1)$$

where Y_{i2006} is the household- or individual-level outcome of interest in 2006, and Treatment_i records whether the individual or household was in a village that received the campaign.[9] Because the sanitation campaign was randomly assigned, observed differences between the two groups after the campaign can be interpreted as a causal treatment effect. That is, β_1 provides an estimate of the effect of the sanitation campaign on the outcomes of interest. To increase the precision of our estimates, we included a set of individual, household, and village covariates (X_i). These include indicators for other health-related behaviors: handwashing by the mother, using an improved water source, and treating drinking water. Because of concerns about the potential endogeneity of these regressors, we only included predetermined (i.e., 2005) levels. Finally, to control for any preexisting differences in outcomes that remain despite ran-

[8] Because all latrines were built right next to the main housing unit, often within the yard or connected to the main house, walking time is set to zero for household members using private latrines. Community latrines were not present in the study area, and reported use of neighbors' latrines was negligible.

[9] For robustness purposes, we also estimated a difference-in-difference model; i.e., we subtracted the baseline (2005) outcomes from the follow-up (2006) outcomes described above. For all outcomes (four health, five nonhealth indicators), the results are qualitatively similar. Thus, for the remainder of the article, we focus on the more standard single difference estimator associated with randomized control trials.

domization, we also estimate models that control for baseline (2005) levels of the outcome of interest:

$$Y_{i2006} = \beta_1 \text{Treatment}_i + \beta_2 X_i + \beta_3 Y_{i2005} + \varepsilon_i. \quad (2)$$

For health indicators, the sample size is lower in model 2 compared to model 1 since model 1 includes all children sampled in 2006 while model 2 only includes children measured in both 2005 and 2006. Thus, we report estimates for both models. For the household-level welfare outcomes, sample size is equal across models 1 and 2 (since all households measured in 2006 were also measured in 2005), so we only report the more robust model 2 results.

The health outcome models, including the model for the binary diarrhea outcome, were run using ordinary least squares on the full panel of households (or individuals) in the sample.[10] The two welfare indicators required different functional forms. We used a Tobit specification in the time cost model to account for the fact that this cost was censored at zero for those household members that used a latrine. An ordered logistic regression model was used for the "satisfaction with sanitation" Likert-scale outcome. Finally, we make two other adjustments. First, all standard errors are clustered at the village level since the treatment was applied at this level. Second, as in table 1, we compute *q*-values (alongside conventional *p*-values) that account for the fact that multiple hypotheses are being tested simultaneously and control the FDR.

IV. Results

Child Health Impacts

Table 2 presents estimates of the impacts of the sanitation campaign on child health outcomes in Bhadrak. The first measure we examine is reported diarrhea among children under 5 in the 2 weeks before each survey. Point estimates on the treatment indicator are negative, indicating that the sanitation campaign is associated with decreased diarrhea rates. These effects are not statistically significant, however. We observe an overall decrease in reported diarrhea prevalence in both treatment and control villages in the second year of the study. Diarrhea rates in this sample were high (as expected) in 2005, with about one-quarter of children experiencing a diarrhea episode in the 2 weeks before the survey (table 1). Rates were also somewhat higher in treatment villages (28%) compared to controls (23%), but this difference was not

[10] We also estimated these models using other functional forms, such as probit and logistic regressions. Results were qualitatively identical to those presented here, so we report results from the simpler linear models.

TABLE 2

ESTIMATES OF THE EFFECT OF THE SANITATION CAMPAIGN ON CHILD HEALTH OUTCOMES

	Diarrhea		MUAC *z*-Score		Height *z*-Score		Weight *z*-Score	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Treatment	−.020	−.021	.20	.30	.37	.52	.26	.31
p-value	.31	.36	.045**	.0011***	.0024***	.000053***	.034**	.0057***
q-value	.31	.36	.06*	.0021***	.0095***	.0002***	.06*	.0075***
Diarrhea 2005		.043		−.18**		−.15		−.21
Lagged (2005) dependent variable				1.92***		1.08***		1.15***
Mother's MUAC / height / weight			.0054	.0073	.044***	.044***	−.0014	−.0011
Population density	−.00081***	−.00081***	.0013	.0012	.0025**	.0023	.0029**	.0027**
Distance to road	.00036	.00027	.00093	.00039	.0023	.0019	.0017	.0016
Open caste	−.036	−.025	−.048	−.021	.023	−.012	−.069	−.088
Mother's education:[a]								
Primary	.0076	.0047	.053	−.077	.23	.23	.12	.14
Secondary+	.0085	.0034	.29***	.17*	.48***	.46***	.22	.20
Own land	−.015	−.020	.030	−.014	−.025	−.14	.11	.071
ln(expenditure)	−.0028	.0034	.024	−.043	.023	.051	.080	.040
TV	.026	.038	.085	.12	.59***	.51***	.26**	.24**
Handwashing mother	−.0035	−.0034	−.0050	−.031	−.0080	−.021	.012	.0087
Improved water	.0048	.016	−.020	.0069	−.037	.017	.12	.11
Treating water	−.014	−.015	.084	.23**	−.017	.019	.084	.24
Breast-feeding	.024	.021	−.15	−.16*	−.35**	−.36**	−.17	−.12
Female	.0067	.0052	.031	−.043	.16	.013	−.041	−.16
Age:[b]								
0–6 months	−.10***		.74***		1.03**		1.20***	
6–11 months	.055		.53***		.16		.62***	
1 year	.019	.0096	.32**	.29*	−.47	−.40	−.35*	−.30
2 years	.032	.028	.16	.23**	−.55***	−.54***	−.29*	−.21
3 years	−.0097	−.0091	.21**	.17*	−.10	−.16	.16	.15
Observations	1,176	1,007	1,066	678	965	724	1,068	775
R^2	.021	.014	.068	.162	.105	.187	.079	.097

Note. Standard errors clustered at the village level, and robust *p*-values calculated for all covariates. For the treatment effect estimate, a false discovery rate–adjusted *q*-value is also shown. MUAC = mid-upper-arm circumference.

[a] Omitted category is less than primary.

[b] Omitted category is 4 years.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

statistically significant. In 2006, diarrhea rates dropped to an overall average of about 14%, with rates in control villages becoming slightly (although not significantly) higher than in treatment villages. This large across-the-board decrease precludes us from detecting a significant impact of the sanitation campaign.

Continuous anthropometric measures provide an alternative way of examining health impacts. Starting with MUAC, estimates with and without controlling for baseline MUAC (model 1 vs. model 2) show that MUAC *z*-scores are 0.20–0.30 standard deviations higher in treatment villages relative to controls after the sanitation campaign (table 2). These effects are significant whether we consider conventional *p*-values or FDR-corrected *q*-values. Similarly, HAZ increased by about 0.37–0.52 standard deviations in treatment villages relative to controls after the sanitation campaign, and WAZ increased by 0.26–0.31 standard deviations. Finally, we note that the children in our sample are quite malnourished by international standards (see table 1). In fact, at every age group, average MUAC for age in the sample falls below the WHO standard fifteenth-percentile growth curves. Average HAZ and WAZ are both more than 2 standard deviations below international standards.

Impacts on Household Welfare

We turn finally to the impacts of the sanitation campaign on household welfare indicators. Table 3 shows that the time that men and women spent walking to defecation sites decreased substantially after the campaign, while levels of satisfaction with sanitation facilities increased. For time costs, the point estimates indicated that both men and women saved about 3.5 minutes one way per defecation trip. Assuming each household member makes one trip (both ways) per day, the total cost savings for each man and woman would be about 7 minutes per day. While latrines are often promoted as having substantial benefits for women specifically, our findings indicate that for time savings, men and women experienced similar benefits. (Of course, latrines may have other important benefits for women, such as safety and privacy.) Children also experienced time savings of about 2.2 minutes per trip or roughly 4.5 minutes per day. Finally, respondents in treatment villages reported levels of satisfaction that were 0.8 points higher (on the 4-point scale) than respondents' satisfaction levels in control villages.

V. Discussion

Do Toilets Improve Health and Welfare?

Our results indicate that the Bhadrak sanitation campaign led to improvements in child health (as measured by anthropometric indicators) and house-

TABLE 3

ESTIMATES OF THE EFFECT OF THE SANITATION CAMPAIGN ON WALKING TIME AND SATISFACTION

	Walking Time for Household Subgroups			
	Men	Women	Children under 5	Satisfaction with Sanitation
Treatment	−3.52	−3.56	−2.22	.84
p-value	.0061***	.0017***	.0039***	.0026***
q-value	.0061***	.0051***	.0051***	.0051***
Lagged (2005) dependent variable	.14***	.15***	.12**	.13**
Population density	.00044	−.0036	−.0031	.0020
Distance to road	.016**	.014**	.0046	−.0058***
Open caste	.036	−.34	−.14	.28*
Mother's education:				
Primary	−2.09**	−1.82**	−1.25*	.26
Secondary+	−2.02***	−2.44***	−1.18***	.092
Own land	.85	.52	.56	−.013
ln(expenditure)	−.85**	−.85**	−.0011	.011
TV	−3.15***	−2.53***	−2.26***	.55***
Handwashing	−.23	−.27*	.10	.057*
Improved water	.59	.27	−.40	.20
Treating water	−.72	−.63	−.61	−.087
Observations	984	988	882	996
Psuedo-R^2	.023	.027	.019	.04

Note. Standard errors were clustered at the village level, and robust *p*-values calculated for all covariates. For the treatment effect, a false discovery rate–adjusted *q*-value is also shown.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

hold welfare. Policy analysts and public health researchers are often interested in the size of such impacts—that is, how community sanitation (e.g., number of toilet users) affects individual health through exposure at the community level (Zwane and Kremer 2007; Bartram and Cairncross 2010; Mara et al. 2010; Pattanayak et al. 2010). Fully attributing the resulting estimates to latrine ownership specifically is somewhat more difficult. While we are confident that the Bhadrak campaign had a large effect on sanitation outcomes, it is possible that this campaign could also have led households to change other health-related behaviors. In this case, the treatment effects we measure would still give a valid estimate of the overall impact of the campaign on health and welfare, but we would be less confident in attributing these changes to latrine uptake per se if other behaviors changed. To partially address this concern, table 4 reports treatment effect estimates for five diverse health-related behaviors reported at the household level: use of an improved water source (tube-well or piped water vs. surface or rainwater), treatment of drinking water, use of an improved cookstove (vs. traditional three-stone stove), handwashing frequency among primary caregivers, and ownership of mosquito nets. None of these other health behaviors improved significantly in treatment villages relative to controls after the campaign. Thus, differences in health and welfare outcomes between

TABLE 4
ESTIMATES OF THE IMPACT OF THE SANITATION CAMPAIGN ON OTHER HEALTH-RELATED BEHAVIORS

	Using Improved Water Source (1)	Treating Drinking Water (2)	Using Improved Cookstove (3)	Handwashing Frequency for Primary Caregivers (4)	Number of Mosquito Nets Owned (5)
Treatment	.0016	−.0057	−.017	.13	−.23
p-value	.84	.78	.11	.41	.05*
q-value	.84	.84	.27	.68	.25
Observations	1,044	1,050	1,050	1,050	1,050
R^2	.0000	.0001	.0024	.0006	.004

Note. Standard errors were clustered at the village level, and robust *p*-values calculated. For the estimate of the effect of the sanitation campaign, a false discovery rate–adjusted *q*-value is also shown.
* Significant at 10%.

treatment and control villages after the campaign cannot be attributed to changes in these other behaviors. Sanitation improvements (i.e., latrine adoption) are likely a key pathway linking the campaign to health and welfare.

Under this interpretation, the basic story appears to be that decreasing open defecation reduced fecal contamination of the community environment. These improvements may have led to moderate reductions in self-reported diarrhea and clear improvements in children's nutritional status—arm circumference, height, and weight. Households also saved time and were more satisfied with their sanitation conditions.

Breaking this story down, a few points are worth noting. Our results highlight the importance of using multiple indicators of children's health outcomes. Our inability to detect statistically precise reductions in diarrhea alone may be the result of two related factors. First, our sample may be underpowered to detect a change in a binary outcome such as diarrhea, which contains less information than a continuous indicator. Thus, while our point estimates all point in the direction of decreased diarrhea in treatment villages relative to controls, these results are not statistically significant. Second, in the second year of our study some unknown factor caused self-reported diarrhea rates to be substantially lower than expected in both treatment and control villages. Our measurement of diarrhea applied a consistent method across the 2 years of this study, using accepted protocols for self-reported illness that are used in the DHS. Possible explanations for this decline include survey effects (Zwane et al. 2011),[11] environmental influences such as timing and intensity of the rainy

[11] More recent appraisals call for dedicating more time and resources to measure longitudinal prevalence (Schmidt et al. 2007). Clearly, expending more time and budget to conduct more extensive measurements (e.g., visiting each home 12 times a year) can improve the signal on longitudinal diarrhea prevalence. However, this approach is not typical or practical for the social science randomized trials that aim to link drivers of behavior change to health outcomes. Furthermore, while we are

season across the 2 years of our study,[12] and secular improvements (i.e., applying to both treatment and control villages) in improved water source and handwashing in the second year of the study (see table 4).[13] A combination of these factors may have reduced our study's ability to detect significantly different rates of diarrhea between groups.

If diarrhea were our only measure of health outcomes, we would thus conclude that the sanitation campaign had no discernible impact on children's health status. However, because we also collected data on anthropometry, we are able to use more stable, continuous indicators and detect improvements in *z*-scores for arm circumference, height, and weight. Our results are consistent with the hypothesis that reductions in the overall parasite load in the population decreased both acute disease and malnutrition among children exposed to the campaign. Other studies have similarly found that subclinical "environmental enteropathy" (a disorder caused by fecal contamination that increases the small intestine's permeability to pathogens while reducing nutrient absorption) can cause malnutrition, stunting, and cognitive deficits without necessarily manifesting as diarrhea (Petri et al. 2008; Humphrey 2009).

To our knowledge, this is one of the first studies to carefully examine and deliver credible empirical results on the size and nature of sanitation impacts in the developing world. In particular, we are not aware of any other studies that examine the health impacts of sanitation improvements using a randomized study design, with the exception of a recent study in Madhya Pradesh (Patil et al. 2013). However, our results seem to confirm the findings of a handful of observational studies on this topic. For example, evidence from Indian district-level data (as opposed to household or individual level) suggests that the Total Sanitation Campaign increased children's HAZ by 0.2 standard devia-

glad that there is greater clarity in public health literature now, we note that our study protocol (using 2-week recall) followed best practices at the time it was finalized in 2004.

[12] Carlton et al. (2014) show that diarrhea prevalence has a complicated relationship with rainfall timing and intensity; heavy rainfall after dry periods can positively affect incidence, while heavy rainfall after wet conditions can decrease incidence. During our fieldwork, we observed higher levels of rainfall and flooding during the baseline (2005) compared to the follow-up round of surveys. However, more granular data from the study area (at the level of villages for specific days of our survey) are not available to more thoroughly explore this hypothesis.

[13] Following a referee suggestion to further examine this hypothesis, we ran additional "triple-difference" analyses in which the improved water source and handwashing indicators were interacted with a treatment × 2006 variable in the health regressions. These regressions essentially look at whether the effect of the sanitation campaign was stronger in households that used an improved water source (or washed hands more frequently). We see no discernible patterns in the results, perhaps because our sample does not have statistical power to discern these third-order effects.

tions (Spears 2012), somewhat lower than the roughly 0.4 standard deviation effect we find in Bhadrak after a more intensive, targeted sanitation campaign. Similarly, analysis of DHS data from eight countries comparing children with intermediate sanitation to children with no sanitation facilities suggests increases in height for age among rural children in the range of 0.06–0.22 standard deviations (depending on different levels of water supply; Esrey 1996). A more recent appraisal using data from over 70 countries in the DHS meta-data-set finds a link between improved sanitation and reduced risk of stunting (Fink et al. 2011). Similar height-for-age effects are also reported by other observational sanitation studies: Daniels et al. (1991; 0.27 standard deviations), Merchant et al. (2003; 0.37–0.39 standard deviations), and Lavy et al. (1996; 0.2 standard deviations).

We can also compare our results to other child-health programs. For example, children in the treatment group of the Progressa conditional cash transfer program were 0.96 centimeters taller than children in the control group (Gertler 2004). When we run our models using raw height (in centimeters) rather than *z*-scores, the effects we observe are between 0.9 and 1.5 centimeters. In a setting that is more similar to our sanitation intervention, a water source improvement (spring protection) program in Kenya reduced diarrhea by 4–5 percentage points and found a marginally significant increase in body mass index of 0.2 kilograms/meter^2 (Kremer et al. 2011; results for weight were not significant, and height and arm circumference results were not reported).

Our results also indicate that the benefits of latrine ownership extended beyond health effects. We find that adult household members saved an average of roughly 7 minutes a day in time spent walking to and from open defecation sites. It is quite possible that these immediate, tangible benefits of latrine use play an important role in inducing households to change their behavior. Indeed, the "convenience" of latrines is often highlighted in CLTS and other sanitation promotion messages. Finally, we observe that households in campaign villages were more satisfied with their sanitation conditions. Indeed, these perceptions may be key to the longer-term sustainability of sanitation-related behavior change in this area.

We are also careful to note that these results capture the short-term impacts of this sanitation campaign (i.e., the impacts that were observed in the year after the intervention). Reported impacts may be lower bounds on the full health impacts because we cannot demonstrate any potential long-term and intergenerational gains arising from epigenetic mechanisms (Barker 2001). But, longer-term impacts are contingent on continued use and maintenance of latrines.

Are Toilets a Cost-Beneficial Investment?

While our results indicate that toilets generate benefits, economists are in a unique position to evaluate whether these benefits exceed costs for both households who must make the choice to invest in toilets and policy planners who are trying to influence households' investment choices. From a public health perspective, reductions in diarrhea and resulting improvements in nutritional status (and child survival) are the main motivation for investing in sanitation improvements. However, as noted throughout the article, households themselves may care as much or more about the more immediate, private nonhealth costs and benefits. Although others have attempted to conduct cost-benefit analyses using macro or regional data that require strong assumptions (Hutton, Haller, and Bartram 2007; Whittington et al. 2008), we are the first to quantify some of these payoffs—from the perspective of a household in Bhadrak—to understand households' decisions in the Orissa setting. Table 5 summarizes the sanitation-related costs and benefits we consider, along with the methods and parameters we use and our resulting value estimates.

Costs

Following Whittington et al. (2008), our unit of analysis is cost per month to an average household of constructing and maintaining a latrine. The choice of a discount rate is, as usual, somewhat tricky. Whittington et al. use a 4.5% discount rate, but they analyze costs from the government or social planner's perspective. Because we are interested in perceived costs to the household, we choose a higher discount rate of 20% for our analysis. Thus, our approach is conservative: if latrine benefits exceed costs at a high discount rate, we can be certain that they will in settings (e.g., better-functioning credit markets) with lower discount rates.

Monthly construction costs are simply the cost of construction times the capital cost recovery factor (see table 5). We calculate that construction costs are $0.75 per month for an unsubsidized latrine, and $0.13 for a subsidized latrine. Assuming households spend 1 hour per month on latrine upkeep and valuing household members' time at 30% of the local wage rate, we estimate monthly latrine maintenance cost of $0.06 per household.[14] Adding the costs for construction and maintenance, the total costs per month are $0.81 per household for an unsubsidized latrine, and $0.19 for a subsidized latrine.

[14] Pattanayak et al. (2005, 2010) discuss how to value time inputs and review the valuation literature related to drinking water. We omit the small onetime costs to households of participating in the campaign activities.

TABLE 5
ESTIMATED COSTS AND BENEFITS OF SANITATION IMPROVEMENTS IN BHADRAK

			Estimated Monthly Value ($)	
Cost or Benefit	Parameters Used to Estimate Value	Citation	Unsubsidized	Subsidized
Construction cost	Unsubsidized cost = 1,500 rupees ($30); subsidized cost = 300 rupees ($5)	Our data	.75	.13
	Monthly cost = construction cost/12 × capital cost recovery factor: CCRF = $r(1+r)^d/[(1+r)^d-1]$	Whittington et al. (2008)		
	Amount of time until latrine needs to be replaced (d): 6 years	Our data		
	Discount rate (r): 20%	Assumption		
Maintenance cost	1 hour per month on latrine upkeep	Whittington et al. (2008)	.06	.06
	Daily wage in Bhadrak: $1.50	Our data		
	Time valued at 30% of wage rate	Whittington et al. (2008)		
Total costs			.81	.19
Health benefit:				
Diarrhea related:				
Mortality reduction	30% reduction in diarrhea incidence (4.5 to 3 cases/household/year); case fatality rate of 8/10,000; value of statistical life = $30,000	Whittington et al. (2008)	.78	.78
Cost of illness	30% reduction in diarrhea incidence (4.5 to 3 cases/household/year); cost of illness of $6 per episode	Whittington et al. (2008)	.19	.19
Nutritional status:				
Mortality reduction	Not valued		. . .	. . .
Human capital improvement	Sanitation campaign improves height-for-age z-score by 0.4	Our results	.39	.39
	1 z-score increase in height for age increases future wage by 8%	Victora et al. (2008)		
	Daily wage in Bhadrak: $1.50	Our data		
	Discount rate: 20%	Assumption		
	Representative household has 2-year-old child who starts working at age 16 and continues to work until age 66	Assumption		
Nonhealth benefit:				
Time cost savings	Travel cost avoided from switching to latrine = 7 minutes per adult per day	Our results	1.09	1.09
	Representative household has five adults	Assumption		
	Daily wage in Bhadrak: $1.50	Our data		
	Time valued at 30% of wage rate	Whittington et al. (2008)		
Psychic/emotional benefit	Not valued		. . .	. . .
Total benefits			2.45	2.45
Benefits − costs			1.64	2.26

Benefits

We turn now to the benefits of latrine construction, including both health and nonhealth benefits. There are at least two categories of health benefits to consider. First is the reduction in acute diarrheal illness: reduced costs of illness (e.g., increased productivity and reduced health care costs) and reductions in diarrhea-related mortality. Because we do not find a statistically significant impact on diarrheal diseases within the time frame examined here, we use typical sanitation program estimates reported in Whittington et al. (2008), which amount to combined morbidity and mortality savings valued at roughly $1 per household per month.[15]

Second, health benefits stem from improvements in nutritional status. Prior studies have characterized nutritional improvements in terms of both reduced mortality (Pelletier 1994) and long-term human capital improvements (Victora et al. 2008). Quantifying mortality impacts on the basis of our results would require several additional assumptions about the relationship between nutritional outcomes and mortality in our particular sample. So we leave these values aside for the moment and focus our attention on the human capital improvements, which will be a lower bound. Using our own estimated relationship between latrine adoption and height for age, as well as an estimate reported in Victora et al. (2008) that a 1 point increase in HAZ will increase a child's future wages by 8%, we calculate the present discounted value of future earnings increases for a typical beneficiary household in which a 2-year-old child starts working 25 days/month in year 16 and works until age 66. The resulting monthly net present value of future wage increases is $0.39.

We turn next to the nonhealth benefits, which include psychic benefits (e.g., satisfaction, sense of privacy) as well as time savings relative to open defecation. As Pattanayak et al. (2006) suggest, some of these benefits are harder to monetize than others (e.g., requiring stated preference methods). We do not attempt to monetize satisfaction or other psychic benefits. Instead, turning to time cost savings, our estimate is that households avoided a total of approximately 35 minutes per day in "travel cost" by switching from open defecation to latrine use (7 minutes per adult; approximately 5 adults per household). Again

[15] Whittington et al. (2008) assumed that sanitation improvements would lead to a 30% reduction in diarrhea incidence, from 4.5 to 3 cases per household per year. Adjusting for the fact that not all households adopt and use latrines, this translated to an average per-household benefit of an 8% reduction in diarrhea incidence. The average cost of a nonfatal diarrhea episode was estimated to be $6 per episode, leading to a per household morbidity cost savings of $0.19/month. A case fatality rate of 8/10,000 and a value of statistical life of $30,000 yielded an averted mortality risk benefit of $0.78 per household per month. Thus, the diarrhea-related health benefits are approximately $1 per household per month.

valuing time at 30% of the wage rate, we can translate the time reduction as savings of $0.04 per household per day or $1.09 per month. These benefits alone represent 2% of household income, given that such a household spends (and earns) about $50 per month.

Calculus of Coping

Aggregating the costs and benefits, our analysis suggests that both subsidized and unsubsidized latrines appear to be cost-beneficial investments for the average household in Bhadrak. The net benefits of an unsubsidized latrine are $1.64 per month; subsidy-eligible households would see net benefits of $2.26 (table 5). In fact, we find that time savings alone appear to exceed even the unsubsidized construction and maintenance costs for households that adopted latrines in Bhadrak. This finding is in line with a global-level cost-benefit analysis of water supply and sanitation interventions that found large time savings from improved access to water and sanitation (Hutton et al. 2007).

Before the sanitation campaign in Bhadrak, very few households had adopted latrines. After the campaign, we see a marked increase in latrine adoption among households in treatment villages with no change in latrine ownership within control villages. A reasonable conclusion would be that, before the campaign, many households perceived the costs of latrine adoption to exceed the benefits and that the campaign achieved its success by either reducing costs or increasing benefits (or both) enough to tip the balance in favor of adoption. Our cost-benefit analysis, however, suggests that even in the absence of subsidies households would have faced time savings sufficient to offset any latrine construction costs. Thus, households in control villages and households who built latrines before the campaign could have reaped these benefits, yet they did not. How can we explain this result?

Maintaining the standard economic assumption of rational choice based on perceived costs and benefits, there are two main possibilities: either we have underestimated the costs of latrine construction in the absence of the campaign, or we have overstated the perceived benefits. We address each of these hypotheses in turn.

Turning first to costs, it is possible that the unsubsidized latrine construction cost under the campaign (i.e., the cost paid by subsidy-ineligible above-poverty-line [APL] households in treatment villages) is a poor proxy for the cost of building a latrine before the campaign or in the control villages. The sanitation campaign increased the supply of latrine construction materials and decreased search costs for households interested in building latrines, facilitating construction for APL and BPL households alike. In other words, the campaign may have substantially reduced transaction costs for latrine construction in ways we have overlooked.[16]

At the same time, we also acknowledge the possibility that we have overestimated the benefits of latrine construction. For example, it is possible that households do not value their time savings as highly as the Whittington et al. method assumes (30% of the wage rate). Furthermore, while we have not valued psychic benefits of latrine use, it is also possible that there are important psychic costs associated with changing behavior. Indeed, comments from people we interviewed in Bhadrak suggested that this may be the case for some. For example, while a majority of our informal interviewees emphasized the benefits of latrines (e.g., privacy and convenience for women), there were a small number of respondents who also emphasized the difficulties in changing behavior. One man said: “If [open defecation] *was* good enough for the Maharajas, it’s good enough for me.” Some women said that going out together in the evenings for open defecation gave them a chance to spend time together.

All of these considerations lead to the general point that while we report results in terms of averages, it is likely that costs and benefits vary across the population distribution. That is, while latrine adoption may look like a good decision for the marginal household, there may be a significant proportion of the population for whom costs exceed benefits. If latrines were a purely private good, our analysis might end here—allowing adoption up to the point where private benefits equaled private costs would generate an efficient outcome. However, given that improvements in sanitation are likely to have health benefits that are distributed across the community, the externality and public good aspect of latrines creates the potential for suboptimal sanitation levels. Indeed, this kind of logic likely guided planners in the United States who

[16] Indeed, one way to interpret our results is to use the estimated time savings, which should be more visible to the household than potential health benefits and which should not be affected by the campaign, as a lower bound on the perceived cost of latrine construction for households in control villages. Since we estimate that the average household could achieve time savings of $1.09 per month by building a latrine, the perceived monthly construction, maintenance, and transaction costs must have exceeded this amount for households that did not build latrines. Subtracting out maintenance costs ($0.06/month) and assuming a 20% discount rate, this implies that the perceived construction costs (including initial transaction costs) for the average household not exposed to the sanitation campaign exceed $40 (Rs 2,000). This implies that even for subsidy-ineligible APL households, who paid about $30 for a latrine under the sanitation campaign, latrine costs were reduced more than 25%, while BPL households saw costs drop from at least $40 to $6—an 85% reduction. Of course, these are estimated values for the average household in Bhadrak. Values for individual households would be distributed around these mean values such that the resulting cost-benefit ratios—and, subsequently, sanitation choices—will vary across the population before and after the campaign.

delivered macropublic health interventions (e.g., sanitation, chlorination, and vaccination) that some say help explain at least 50% of the improvements in longevity experienced in this country over the past decade (Preston 1996). In the meantime, we hope that our study has generated a deeper understanding of the drivers and impacts of household sanitation so that evidence-based policies can help close the "sanitation gap" between rich and poor countries and improve the health and well-being of some of the world's most disadvantaged people (Watkins 2006; Bartram and Cairncross 2010).

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