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The Impact of Pro-Poor Sanitation Subsidies in Open Defecation-Free Communities: A Randomized, Controlled Trial in Rural Ghana

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Background: According to the World Health Organization/United Nations International Children's Fund Joint Monitoring Program, 494 million people practice open defecation globally. After achieving open defecation-free (ODF) status through efforts such as Community-Led Total Sanitation (CLTS), communities (particularly vulnerable households) may revert to open defecation, especially when toilet collapse is common and durable toilets are unaffordable. Accordingly, there is increasing interest in pro-poor sanitation subsidies.

Objectives: This study determined the impacts of a pro-poor sanitation subsidy program on sanitation conditions among the most vulnerable households and others in the community.

Methods: In 109 post-ODF communities in Northern Ghana, we conducted a cluster randomized controlled trial to evaluate a pro-poor subsidy program that identified the most vulnerable households through community consultation to receive vouchers for durable toilet substructures. We surveyed households to assess toilet coverage, quality, and use before and after the intervention and tracked program costs.

Results: Overall, sanitation conditions deteriorated substantially from baseline to endline (average of 21 months). In control communities (not receiving the pro-poor subsidy), open defecation increased from 25% (baseline) to 69% (endline). The subsidy intervention attenuated this deterioration (open defecation increased from 25% to only 54% in subsidy communities), with the greatest impacts among voucher-eligible households. Noneligible households in compounds with subsidized toilets also exhibited lower open defecation levels owing to in-compound sharing (common in this context). CLTS followed by the subsidy program would benefit more households than CLTS alone but would cost 21–37% more per household that no longer practiced open defecation or upgraded to a durable toilet.

Discussion: Sanitation declines, often due to toilet collapse, suggest a need for approaches beyond CLTS alone. This subsidy program attenuated declines, but durable toilets likely remained unaffordable for noneligible households. Targeting criteria more closely aligned with sanitation inequities, such as household heads who are female or did not complete primary education, may help to generate greater and more sustainable impacts in Northern Ghana and, potentially, other contexts facing toilet collapse and limited market access. https://doi.org/10.1289/EHP10443

Introduction

As of 2017, approximately 1 of every 16 people in the world practiced open defecation.[1] In sub-Saharan Africa, many countries are not on track to eliminate open defecation by 2030 (part of Target 6.2 of the United Nations' Sustainable Development Goals).[1] In Ghana, for example, nearly one-third of the rural population practices open defecation, with an additional 16% using sanitation facilities classified as unimproved.[1] Progress must increase substantially to promote universal access to safe and sustainable sanitation.

Community-Led Total Sanitation (CLTS) is a widely used approach for sanitation improvement that focuses on bottom-up behavior change, triggered by psycho-social mechanisms and collective action to end open defecation and drive demand for latrines.[2,3] The goal is for communities to achieve "open defecation-free" (ODF) status, which occurs when a community no longer shows visible signs of open defecation and a high proportion of households own and use individual toilets (80–100%, depending on specific country policies).[4] Typically, CLTS avoids financial assistance that may dissuade communities from taking the initiative to address sanitation concerns through internal means. Several studies have provided evidence reinforcing the logic of this zero-subsidy orientation, finding that CLTS is more effective in locations with no prior history of water, sanitation, and hygiene (WASH) subsidies.[5–9]

However, although CLTS programs have improved sanitation outcomes in many communities, evidence is growing that poor and vulnerable households do not benefit equally. These households tend to construct toilets of lower quality,[10–12] sell assets or take on debt to finance unaffordable facilities when unable to build toilets themselves,[12] and are more likely to revert to open defecation.[13–17] Although some studies have found evidence of communities sustaining their ODF status, others have found open defecation levels of up to 57% in the years following ODF attainment, often related to nondurable toilet collapse caused by issues such as flooding and unstable soils.[4,11,14,18–26] Reversion to open defecation can cause public health concerns, including for neighboring households that continue to use toilets.[27]

To address these equity, sustainability, and public health concerns, there is increasing interest in targeted subsidies for poor and vulnerable households. In 2018, Ghana became the first country in sub-Saharan Africa to develop national guidelines for targeted pro-poor sanitation subsidies.[28] Globally, many governments heavily subsidize water supply and sanitation services, but subsidies are often poorly targeted and benefit relatively wealthy households.[29] Effective and efficient targeting represents a key research and implementation challenge, with a current focus on methods such as proxy means testing (where household characteristics function as proxy indicators of wealth) or community-based targeting (where selection is based on community members' direct input).[30–32] Once targeted, subsidies can come in various forms, such as discount vouchers (to purchase a specific market product) or household rebates (after toilet verification).[16,31,33–38]

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To date, robust evidence on the impact of targeted sanitation subsidies remains limited, and most programs combining CLTS with targeted subsidies have been implemented in Asia [e.g., India, Bangladesh, Cambodia, Lao People's Democratic Republic (PDR)].[16,31,34,39,40] For example, a randomized controlled trial (RCT) in Bangladesh investigated the impact of offering discount vouchers to poorer households during interventions similar to CLTS. Compared with villages that only received the CLTS-like intervention, villages also receiving the targeted subsidy program increased individual toilet coverage by 9 percentage points and reduced open defecation by 7 percentage points, with some of these benefits spilling over to nonbeneficiary households.[35] Similarly, household-level rebates (partially covering toilet costs) offered to poor households in Lao PDR were associated with a 7-percentage point increase in individual toilet coverage in the study area.[40] Recently, a hypothetical comparative benefit–cost analysis focused on Ghana suggested that CLTS combined with well-targeted subsidies could be more cost effective than CLTS alone.[41] The subsidy program we evaluate here (providing vouchers for durable latrine substructures in communities already declared ODF) acted as the model for the program considered in that benefit–cost analysis, but the program's impacts were unknown at the time of that analysis.

Accordingly, the primary objectives of this study were *a*) to determine the extent to which this targeted sanitation subsidy program improved sanitation conditions (increased toilet coverage and quality, and reduced open defecation) among the most vulnerable households, and *b*) to determine the extent to which these benefits spilled over to other households. In addition to our primary objectives, this work also offers insight into substantial declines in overall sanitation conditions among study communities, as well as the cost effectiveness of this targeted subsidy in reducing open defecation and increasing access to durable, improved toilets.

Methods

This study took place in Tatale and Kpandai Districts in Northern Ghana. These districts were *a*) program areas of United Nations International Children's Fund (UNICEF)-Ghana, this study's implementing partner, and *b*) not part of a concurrent sanitation subsidy program implemented by Ghana's Community Water and Sanitation Agency. As described below, 109 communities that had previously achieved ODF status in these districts were randomly selected for this cluster-RCT (cRCT), and UNICEF-Ghana initiated a targeted sanitation subsidy program among 59 communities randomly selected from the original 109, referred to as subsidy communities (Table 1). The remaining 50 acted as control communities. Prior to achieving ODF status, CLTS implementation had occurred in all 109 communities. CLTS typically involves efforts to trigger feelings of shame and disgust regarding open defecation, with the goal of motivating communities to address the issue by building unsubsidized toilets.[2] In this context, these unsubsidized toilets tend to be latrines with unlined pits, mud walls, and squatting platforms made from wood and mud. By comparing sanitation conditions in subsidy and control communities before and after program implementation, we evaluated the program's impact on sanitation outcomes.

Summary of the Targeted Subsidy Program

In collaboration with UNICEF-Ghana and the Tatale and Kpandai District Assemblies (DAs), we monitored implementation of a targeted subsidy program that involved *a*) community consultation to identify the most vulnerable households, *b*) distribution of vouchers redeemable for a durable latrine substructure, and *c*) performance-based payments to artisans contingent upon verification of toilet completion (including a superstructure) by district officials.

Table 1. Definitions of sanitation outcomes and other key terms used in this study.

Term	Definition
Sanitation outcomes	
Primary open defecation	A household reported that they practice open defecation as their primary sanitation behavior when at home.
Own and use a functional toilet	A household owned or co-owned a functional toilet, defined as having a full or partial superstructure and a usable pit that was not collapsed or full (verified through observation), and the household reported using the toilet as their primary defecation location when at home. "Co-ownership" indicates multiple households contributed to construction. For simplicity, we refer to both co-ownership and single ownership together as "ownership."
Own and use a durable toilet	A household owned or co-owned a durable toilet, defined as a functional toilet with a full superstructure and a durable substructure, and the household reported using the toilet as their primary defecation location when at home. A durable substructure includes a slab made of concrete or plastic and a pit lined with plastic, rock, brick, or concrete.
Own and use an unshared durable toilet	A household had single ownership of a durable toilet, reported using the toilet as their primary defecation location when at home, and was the only household using the facility (i.e., it was not shared with any other households).
Other key terms related to the trial	
Subsidy community	One of 59 communities included in the treatment group of the study, where community consultation took place, and where facilitators and artisans distributed subsidy vouchers to voucher-eligible households and educated all households on available durable substructure options. Households could redeem vouchers with local artisans for one of three durable toilet substructures, at no cost to the household. The household was responsible for digging the pit and installing the superstructure.
Control community	One of 50 communities included in the control group of the study, where community consultation took place but subsidy vouchers were not distributed.
Voucher-eligible household	A vulnerable household identified as eligible to receive a subsidy voucher through community consultation and follow-up verification, which was present at endline. Communities identified households as vulnerable if they could not feed themselves throughout the year or included a vulnerable person. A vulnerable person was defined as an elderly person over 65 years of age, a person with a severe disability or chronic illness preventing work, a widow, an orphan, or a child household head. Verification confirmed that the household did not already own a durable toilet and did not live in the same compound as another voucher-eligible household.
Noneligible household	A household not identified as eligible to receive a subsidy voucher through community consultation and follow-up verification, which was present at endline. This could be because the household *a*) was not identified as vulnerable during community consultation, *b*) already had a durable toilet, or *c*) lived in the same compound as another eligible household.
Beneficiary household	One of the 441 households identified to receive a voucher during community consultation in subsidy communities. Note that not all of these were present at endline.
Benefitting household	A household that either stopped primary open defecation or upgraded from a nondurable to a durable toilet, regardless of whether the household had received a voucher.

Community consultation is often perceived as providing a more nuanced view of poverty levels within communities as a result of local knowledge of short-term shocks and household support.[30] All households were invited to participate in community consultation meetings where the community identified the most vulnerable households that either *a*) were unable to feed themselves throughout the year, or *b*) included a vulnerable person (elderly person >65 years of age, person with a severe disability or chronic illness preventing work, widow, orphan, or child household head) receiving no support from relatives.[42] Before the program, district officials and community members helped define these criteria. Trained DA (local government) facilitators carried out the identification process in each community, which included community entry, community consultation, and follow-up verification questionnaires (Figure S1). Follow-up questionnaires helped confirm that households identified during community consultation met eligibility criteria and screen out those who already owned a toilet with a durable substructure or lived in a multihousehold compound with another identified household. Only one beneficiary household was selected per compound because multihousehold compounds and in-compound toilet sharing are common in Northern Ghana; the household meeting the highest number of vulnerability conditions was selected as the eligible beneficiary. DA facilitators did not mention the subsidy program during this identification process.[42]

DA staff distributed sanitation subsidy vouchers from February to March 2020. Voucher-eligible households received a voucher covering the full costs of a durable latrine substructure, which included a durable slab and pit lining (Table 1). Households were responsible for digging the pit and building the superstructure (themselves or with help). The vouchers allowed eligible households to choose one of three substructure options (Figure S2): *a*) masonry, consisting of a poured concrete slab and cement block lining, with materials and labor valued at 131–135 USD per substructure across the two study districts; *b*) precast concrete, consisting of a molded concrete slab and lining, valued at 111–118 USD; or *c*) Digni-Loo, consisting of a plastic slab and lining, valued at 103–118 USD.[42] These costs included labor, materials, and transport. Local stakeholders viewed these three substructure options as being more durable than typical unsubsidized toilet construction methods in the region, although we did not assess the relative lifetimes of the three durable substructure options. Recipients redeemed their vouchers with local artisans, who installed the substructure at no cost to the recipient.

Following a performance-based payment system, artisans received 40% of the contracted fee as a down payment, 40% after completion and quality control (i.e., the District Health Environmental Officer and District Engineer verified that the substructure met quality standards and the superstructure was complete), and 20% after 2 months with no reported structural issues.[42] UNICEF-Ghana and their development partner (Global Affairs Canada) provided funding for these payments through local financial institutions.

Community Selection Process

Initially, we randomly selected 100 communities in our two study districts in the presence of DA staff to ensure transparency. A total of 50 were randomly assigned to the subsidy group and 50 were assigned to the control group. A community needed to meet the following two criteria to be eligible for the study: *a*) It had achieved ODF status during or before December 2018, and *b*) it contained 15–150 households, according to UNICEF's database. In Ghana, ODF status is verified by DA officials, who visually inspect the community to ensure there are no observable signs of open defecation and at least 80% of households have latrines.[4] Notably, however, our inspection of implementation databases revealed that the definition of "household" used during these assessments could vary and that some DA officers may have conflated compounds with households. In practice, then, it is possible that some verified communities may not have truly attained the specified conditions.

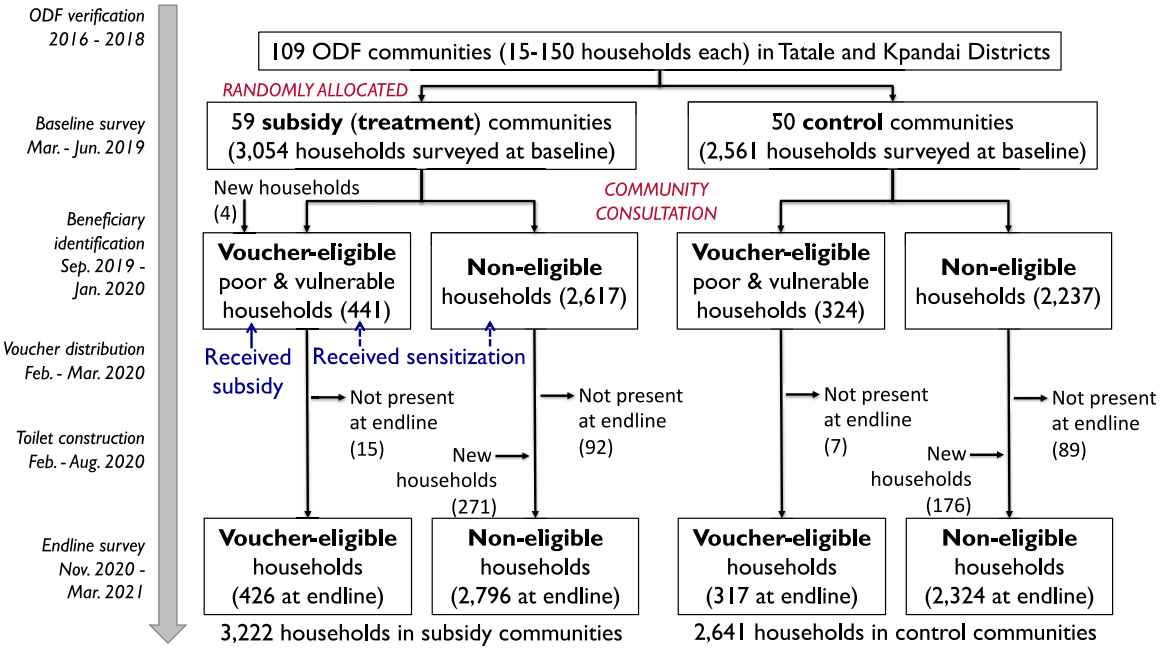

Figure 1. Summary of study flow and populations throughout the randomized controlled trial in Northern Ghana. The subsidy provided to voucher-eligible households in subsidy communities took the form of a voucher that could be redeemed with local artisans for one of three durable substructure options at no cost to the household. The sensitization received by subsidy communities involved education from DA officials and artisans on the available substructure options. See Table 3 for additional details on the numbers of households present at baseline and endline, reasons for household attrition between baseline and endline, and subsidy program implementation. Note: DA, District Assembly; ODF, open defecation-free.

The randomization process was as follows:

1. For each district (Tatale and Kpandai), we recorded all communities that were ODF and had 15–150 households.
2. We read out each community name, and the DA staff confirmed whether it was ODF. Names of the communities that were identified as ODF by the DA staff were written on pieces of paper that were folded and placed in a bag.
3. The DA staff randomly picked names of the communities from the bag, with each selected community being assigned to the subsidy or control group in an alternating fashion.
4. The DA staff then flagged any control communities that were <2 km from subsidy communities. To avoid intercommunity conflicts and contamination of the control group, we removed each control community within 2 km of a subsidy community and replaced it with another one selected randomly from the bag.

The selection in Kpandai occurred on 5 March 2019, during which we randomly selected 26 communities (13 subsidy and 13 control). The Tatale selection occurred on 21 March 2019, with 74 communities being selected (37 subsidy and 37 control). The number of selected communities in each district was proportional to that district's number of eligible communities.

Notably, during baseline data collection, we discovered that additional adjustments were needed. After further consultation with DA staff, the following changes were made before the subsidy program began:

1. Four subsidy communities selected during randomization were identified as subsections of broader agglomerations. In other words, there were other subsections immediately adjacent to the selected ones. To avoid conflicts, we included the additional subsections to cover the entire agglomeration, resulting in the addition of seven subsidy communities.
2. Four non-study ODF communities were <2 km from a subsidy community. These communities were also added to the subsidy group to avoid intercommunity conflict.
3. Four control communities were <2 km from a subsidy community but had not previously been identified as such during the selection process. In these cases, each pair, consisting of the control community and nearby subsidy community, was randomly reassigned to either the control or the subsidy group to avoid intercommunity conflict and any contamination of control communities. Three pairs were reassigned to the control group and one was reassigned to the subsidy group.
4. One community in the control group was smaller than 15 households and was excluded from the study. An additional control community contained 153 households and was retained in the study.

After these adjustments, our final sample included 109 communities, of which 59 were in the subsidy group and 50 were in the control group. Characteristics of subsidy and control communities were similar (Table S1).

Cluster Randomized Controlled Trial Testing the Program's Impacts

Following community selection, we implemented the cRCT in three distinct phases: *a*) baseline data collection (March – June 2019), *b*) targeted subsidy implementation (September 2019–August 2020), and *c*) endline data collection (November 2020–March 2021; Figure 1). At baseline and endline, we surveyed all households in study communities (details below). We tracked sanitation outcomes using the following indicators (Table 1):

1. Households reporting that they practice open defecation as their primary sanitation behavior when at home ("primary open defecation"). We focused on open defecation rather than toilet use (the opposite) because open defecation is more commonly measured in sanitation studies.[25,43]
2. Households owning and using a functional toilet. We defined a functional toilet as having a complete or partial superstructure and a usable pit (i.e., not collapsed or full, verified through observation), and "use" of the toilet indicates that it was reported as the household's primary defecation location. "Ownership" includes both single ownership, where one household built and controlled the facility, and co-ownership, where multiple households contributed to construction.
3. Households owning and using a durable toilet. We defined durable toilets as functional toilets with full superstructures and durable substructures (plastic, rock, brick, or concrete pit lining, and concrete or plastic slab verified through observation). This indicator represents a subset of the previous indicator.
4. Households owning and using an unshared durable toilet. In this context, many households that own a toilet share it with others (non-owners). This indicator shows the degree of individual (single-household) ownership and use, and it represents a subset of the previous indicator.

Notably, a relatively small fraction of households did not practice primary open defecation despite not owning a functional toilet. Instead, these households were allowed to share toilets owned by others. Such households did not fall under indicators 1 or 2. In addition to these sanitation outcomes, the survey also covered topics such as toilet satisfaction, toilet ownership history, toilet sharing, household demographics, and asset ownership.

Between baseline and endline, local DA facilitators, artisans, and financial institutions implemented the targeted subsidy program. The community consultation process occurred in all 109 study communities (subsidy and control groups), enabling us to evaluate impacts of the program specifically for voucher-eligible households and for noneligible households. Community consultation identified $\sim 17\%$ of all households (across subsidy and control communities) as the most vulnerable. After verification, 14% were voucher-eligible (Table 1). Households were primarily deemed ineligible during verification if they lived in compounds with other identified households (with only one voucher provided per compound). In subsidy communities only, facilitators and artisans distributed vouchers to eligible households and educated all households on available durable substructure options. Control communities did not receive vouchers or the accompanying community-wide communication (Table 1), although UNICEF plans to implement the program in control communities now that the study is complete. During implementation in subsidy communities, we monitored and tracked program implementation costs. These costs included salaries and transport for DA facilitators, management of artisan payments by local financial institutions, training, and project management, monitoring, and oversight. We also tracked the costs of the subsidies themselves, including the materials and installation needed for the durable substructures.

Survey Procedures

Study enumerators conducted baseline surveys from March to June 2019 and endline surveys from November 2020 to March 2021 (Figure 1). Surveys occurred concurrently in subsidy and control groups, with an average of 21.3 months between baseline and endline in subsidy communities, and 20.3 months in control communities. Enumerators obtained written informed consent and administered questionnaires to surveyed households and each community's chief and natural leader. Through consultations with local actors, we defined a household as a group of individuals residing in the same dwelling who either cooked and ate meals

Table 2. Summary of variables used in logistic regression models to test the impacts of the subsidy program in Northern Ghana, measured using endline surveys conducted from November 2020 to March 2021.

Variable	Number of households or compounds (n)	Household or compound regression model	Variable type	Data collection method	Summary statistic across full population[a]
Outcome variables					
Primary open defecation	5,749 households	Household	Binary	Household endline survey	61 (59, 62)
Own and use a functional toilet	5,854 households	Household	Binary	Household endline survey, direct observation	24 (23, 25)
Own and use a durable toilet	5,854 households	Household	Binary	Household endline survey, direct observation	9 (8, 10)
Own and use an unshared durable toilet	5,849 households	Household	Binary	Household endline survey, direct observation	3 (3, 4)
Any household owns and uses a functional toilet	3,538 compounds	Compound	Binary	Aggregated from household endline survey, direct observation	31 (29, 32)
Any household owns and uses a durable toilet	3,538 compounds	Compound	Binary	Aggregated from household endline survey, direct observation	12 (11, 13)
Primary explanatory variable					
Subsidy program implementation	5,863 households	Both	Binary	Presence in subsidy or control community	55 (54, 56)
Household-level covariates					
Household size	5,862 households	Household	Integer	Household endline survey	7.0 ± 4.0
Wealth quintile	5,863 households	Household	Integer	Derived from asset ownership reported in household endline survey	3.0 ± 1.4
Household has children <5 years of age	5,858 households	Household	Binary	Household endline survey	71 (70, 72)
Household head completed primary education	5,824 households	Household	Binary	Household endline survey	17 (16, 18)
Female household head	5,862 households	Household	Binary	Household endline survey	11 (10, 12)
Vulnerable household head	5,345 households	Household	Binary	Household endline survey	19 (18, 20)
Compound-level covariates					
Number of households in compound	5,863 households	Both	Integer	Aggregated from household endline survey	2.3 ± 1.5
Number of people in compound	3,541 compounds	Compound	Integer	Aggregated from household endline survey	11.6 ± 7.6
Median wealth quintile of households	3,541 compounds	Compound	Continuous	Aggregated from household endline survey	3.1 ± 1.3
Any household has children <5 years of age	3,541 compounds	Compound	Binary	Aggregated from household endline survey	81 (80, 83)
Any household head completed primary education	3,541 compounds	Compound	Binary	Aggregated from household endline survey	24 (23, 26)
Any household head is female	3,541 compounds	Compound	Binary	Aggregated from household endline survey	16 (15, 18)
Any household head is vulnerable	3,541 compounds	Compound	Binary	Aggregated from household endline survey	26 (25, 28)
Community-level covariates					
Time since ODF verification	5,796 households	Both	Continuous (months)	Local records	36.1 ± 6.9
Distance to roads	5,863 households	Both	Continuous (kilometers)	Measured through GIS mapping	5.4 ± 4.9
Presence of rocky soil	5,863 households	Both	Binary	Village leader endline survey	31 (30, 33)
Presence of VSLA	5,789 households	Both	Binary	Village leader endline survey	41 (40, 42)
Presence of fines for open defecation	5,789 households	Both	Binary	Village leader endline survey	4 (4, 5)
Previous fines for open defecation that are no longer in place	5,789 households	Both	Binary	Village leader endline survey	47 (46, 49)

Note: Each n-value shows the number of households with data for that variable, except for those only relevant for the compound regression model. In those cases, n-values reflect the number of compounds with data. CI, confidence interval; GIS, geographic information system; ODF, open defecation free; VSLA, village savings and loan association.
[a]Summary statistics for binary variables show the proportion (%) of households among the study population (with 95% CIs), whereas those for continuous and integer variables show the mean value ± standard deviation across all households in the study population. For variables only used in compound-level regression models, the summary statistic reflects the proportion or mean across all compounds in the study. n-Values are provided for each variable to account for any missing values.

together or recognized the same household head (primarily responsible for making financial decisions). Local guides identified community boundaries, and we surveyed all households within these boundaries where an adult was present and willing to be surveyed over the course of up to three visits. Respondents <18 years of age were excluded. Any adult household member present was deemed suitable to participate in the interview, although we prioritized household heads if available.

Enumerators administered surveys in local languages (Lekpapa, Dagbani, or Twi) and recorded responses in the CommCare mobile phone application (version 2.45; DiMagi, Inc.). Survey supervisors conducted checks on $\sim 10\%$ of completed surveys to ensure quality. A senior researcher reviewed answers to a subset of survey questions daily and clarified inconsistent responses with enumerators. The Western institutional review board in the United States (20190382) and the Council for Scientific and

Table 3. Sampling details of households during baseline and endline surveys in Northern Ghana, and subsidy program implementation reported during endline surveys.

Indicator	Control households	Subsidy households	All households
Households surveyed at endline	2,641	3,222	5,863
Surveyed at baseline	2,465	2,947	5,412
New households	176	275	451
Households not surveyed at endline			
Surveyed at baseline	96	107	203
Migrated out of community	60	61	121
No adult available after three attempts	22	26	48
Household has merged with another household	9	14	23
Household members are deceased	4	6	10
Declined to participate	1	0	1
New households	0	4	4
No adult available after three attempts	0	4	4
Subsidy program implementation			
Voucher-eligible households surveyed at endline	317	426	743
Voucher-eligible households that at endline reported receiving vouchers	—	363	—
Noneligible households that at endline reported receiving vouchers	—	88	—
Self-reported voucher recipients at endline who reported constructing a subsidized toilet	—	446	—
Masonry	—	126	—
Precast concrete	—	170	—
Digni-Loo	—	150	—
Self-reported recipients using subsidized toilets	—	358	—

Note: Baseline surveys occurred in March–June 2019, whereas endline surveys occurred in November 2020–March 2021. —, not applicable.

Industrial Research in Ghana (RPN 001/CSIR-IRB/2019) approved the study. We registered the trial protocol with ClinicalTrials.gov under identifier NCT03822611.

Analysis of Subsidy Program Impacts

To determine the subsidy program's effects on sanitation outcomes, we first calculated changes in sanitation conditions between baseline and endline; we then examined differences between households in subsidy and control groups using chi-square tests. To estimate the specific impacts of the subsidy program, we conducted several multivariate logistic regressions on the endline data with adjusted standard errors to account for community clustering.[44] We also considered adjusted standard errors for clustering at the compound level; models with community clustering were more conservative with respect to statistical inference, so we moved forward with community clustering. We computed models among *a*) all households, *b*) voucher-eligible households, and *c*) noneligible households. Including regression models focused specifically on eligible and noneligible households enabled us to test the program's effects on each group and understand whether benefits spilled over to noneligible households.

For each set of households, we constructed four logistic regression models focused on primary open defecation, functional toilet ownership and use, durable toilet ownership and use, and ownership and use of unshared durable toilets (Table 2). In each model, the primary explanatory variable was whether a household was in a subsidy community, where community consultation and voucher distribution were fully implemented. We also controlled for 13 additional household-, compound-, and community-level variables (Table 2) that had potential relationships with sanitation outcomes at baseline[44] and endline based on bivariate regression models (Table S2). These covariates included household size; wealth quintile, derived from reported asset ownership; whether children <5 years of age were present; whether the household head had completed primary education; whether the head was female; whether the head was vulnerable, defined here as elderly, physically or mentally challenged, or chronically ill; the number of households in the compound; the time since the community's ODF verification; the distance from the community to a road; the presence of rocky soil in the community; whether the community had a village savings and loan association (VSLA) at endline; whether the community had fines for open defecation at endline; and whether the community previously had fines for open defecation but no longer did at endline. We included the final covariate, on previous fines for open defecation, because several community leaders reported this scenario.

In addition to household-level models, we also conducted compound-level regressions to test whether any compound members owned and used *a*) a functional or *b*) a durable toilet, because in-compound toilet sharing was common. Again, we computed these models for all compounds, those containing a voucher-eligible household, and those without eligible households. We included the same covariates, with the six household-level variables modified to reflect overall conditions within the compound, as follows: total number of people in the compound; median wealth quintile among households in the compound; whether any household had children <5 years of age; whether any household head had completed primary education; whether any head was female; and whether any head was vulnerable (Table 2).

When reporting results from logistic regressions, we present odds ratios (ORs) with 95% confidence intervals (CIs) and *p*-value. Generally, we consider *p*-values <0.05 to represent statistically significant results, although we follow Amrhein et al.[45] in not immediately dismissing a *p*-value slightly >0.05. All analyses were conducted in R (version 4.0.2; R Development Core Team).

Analysis of Program Cost Effectiveness

The costs associated with the subsidy program as implemented during this study have been reported previously.[42] The subsidy itself cost an average of 120 USD per beneficiary household identified during program implementation ($n = 441$), whereas program implementation costs averaged 148 USD per beneficiary household. Overall, the program cost 268 USD per beneficiary household, or a total of 118,000 USD across all subsidy communities.[42] To consider the cost effectiveness of the program, we first considered possible cost reductions that could occur if the program were implemented on a larger scale. Then, we considered its impacts on sanitation conditions by comparing changes in sanitation outcomes within subsidy and control communities. Finally, we compared the costs and impacts associated with CLTS followed by the subsidy program, represented by subsidy communities, to those associated with CLTS alone, represented by control communities. We estimated CLTS costs based on a reported average for Ghana of 30 USD per targeted household.[4] The term targeted households corresponds to all households in communities where CLTS was implemented. Note that we calculated the total number of households as the average from baseline and endline.

We considered the following cost reduction opportunities if the subsidy program were implemented on a larger scale. First, we would expect training, program management, and financial institutions to become more efficient if the program were implemented among more communities across a wider area. For example, managers can cover more communities across larger geographic extents. In addition, combining implementation with other programming—such as CLTS triggering, verification, or follow-up visits—could substantially reduce field costs, given that the

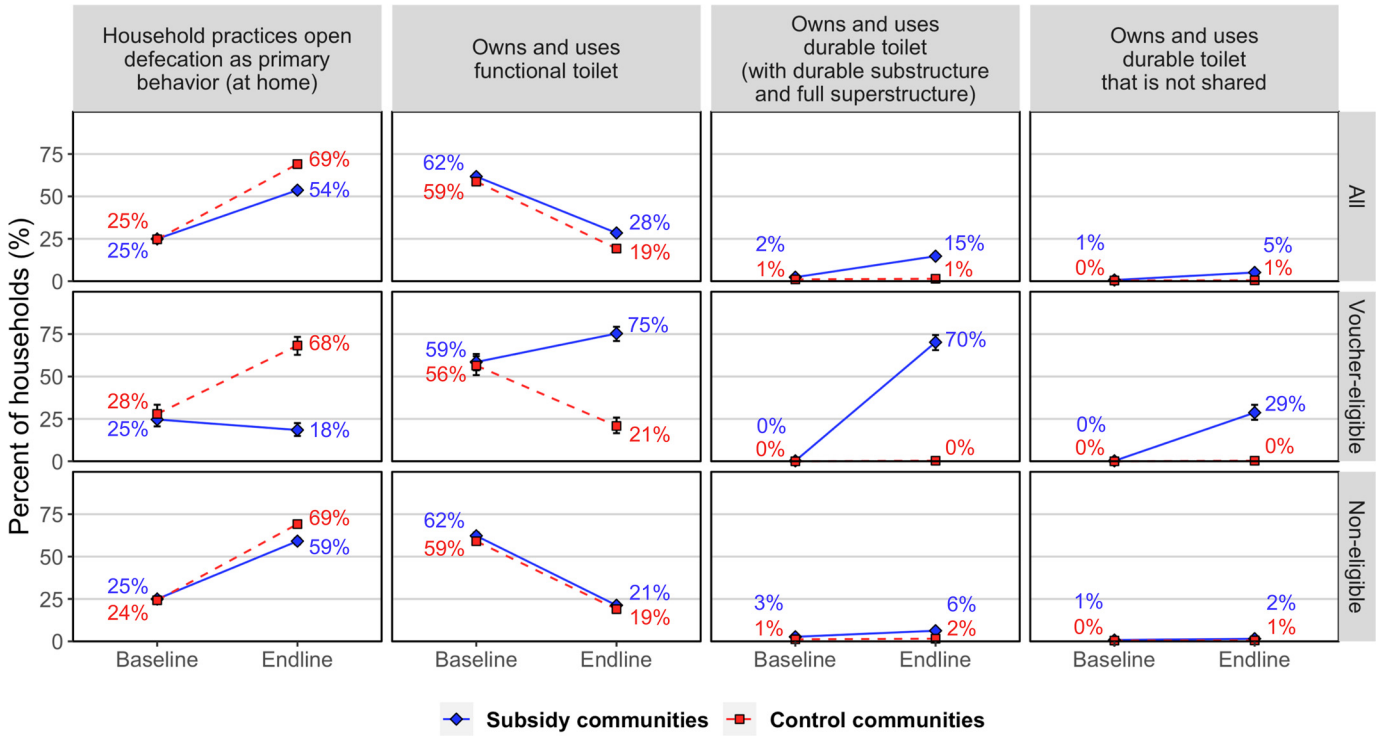

Figure 2. Sanitation outcomes in subsidy and control groups at baseline and endline. Baseline surveys occurred in March–June 2019, whereas endline surveys occurred in November 2020–March 2021 in Northern Ghana. Each column of plots focuses on one of our primary sanitation outcomes: primary open defecation, ownership and use of functional toilets, ownership and use of durable toilets, and ownership and use of unshared durable toilets. Each row of plots focuses on a specific subset of households (all households, only voucher-eligible households, and only noneligible households). Points represent proportions calculated from survey responses, with error bars representing 95% CIs of the proportions shown. For points without visible error bars, CIs do not extend beyond the point symbol shown on the plot. Among voucher-eligible households, 85% reported at endline that they had actually received a voucher. Please note that the proportions of households owning and using durable toilets (third column) include those households owning and using unshared durable toilets (fourth column), meaning that these percentages are not additive. Similarly, the proportions of households owning and using functional toilets (second column) include those who owned and used durable toilets (third column). See Tables 4–6 for corresponding numerical data, *n*-values, additional details on sanitation conditions, and *p*-values associated with chi-square tests for differences between groups. Note: CI, confidence interval.

programs would share costs associated with staff salaries, transport, and similar items. Based on these opportunities, we assumed that field implementation costs could decrease by up to 50% and that project management costs could decrease by up to 25%. Under these conditions, the overall cost of the subsidy would become 209 USD per beneficiary household, or a total of 92,000 USD across all subsidy communities in the study.

To compare changes in sanitation outcomes across subsidy and control communities, we estimated the number of households benefitting in two distinct ways from the program, going beyond only those who received a voucher. Note that these categories represent net improvements given that we also accounted for households going in the opposite direction, such as those reverting to open defecation:

1. Those upgrading from owning and using a functional but nondurable toilet to owning and using a durable toilet
2. Those no longer practicing open defecation as their primary behavior.

We acknowledge that these two categories represent distinct types of changes that may not be perfectly additive, but we also note that these categories are conservative. For example, we do not include other improvements less directly connected with the primary objectives of the subsidy program, such as movement from occasional open defecation to no open defecation at all.

We thus calculated the number of benefitting households as the number of households no longer practicing primary open defecation plus the number of households that upgraded from nondurable to durable toilets minus the number of households that reverted to open defecation or nondurable toilets. We then estimated the cost of the subsidy program per benefitting household by calculating the net percentages of households in subsidy communities falling into each category and subtracting the same net percentages from control communities. Essentially, this procedure provided the net improvements that we can attribute to the subsidy program, assuming that changes in the control group would have occurred to the same degree in subsidy communities if the program had not been implemented. The total cost of the subsidy program, including subsidy and program implementation costs, but not household inputs for pit excavation and toilet superstructure, was divided by the resulting number of benefitting households to arrive at a cost per benefitting household.

We applied the same logic to a comparison of CLTS alone, represented by control communities from before CLTS implementation to our endline surveys, and CLTS followed by the subsidy program, represented by subsidy communities. We began with conditions reported prior to CLTS implementation in our study communities, with toilet coverage estimated at 4% in control communities and 6% in subsidy communities, based on UNICEF's database containing pre-CLTS data for the majority of our study communities. We then calculated our two categories of improvements from before CLTS until our endline surveys. Note that this analysis reflected the overall difference from the starting point (prior to CLTS) to the end point (endline surveys), and did not rely on any intermediate data points, such as our data from baseline surveys. In addition, this analysis did not account for differences in the continued longevity of durable or nondurable toilets after endline. We expect that durable toilets will

Table 4. Descriptive statistics concerning sanitation infrastructure and behaviors at baseline and endline among households in subsidy and control communities.

	Endline			Baseline		
Indicator	Subsidy communities	Control communities	p-Value	Subsidy communities	Control communities	p-Value
Toilet ownership and use						
Ownership and use of functional toilet[a]	28 (27, 30; $n=3{,}214$)	19 (18, 21; $n=2{,}640$)	4.2×10^{-16}	62 (60, 63; $n=2{,}944$)	59 (57, 61; $n=2{,}460$)	2.5×10^{-2}
Ownership and use of functional toilet with full superstructure	26 (25, 28; $n=3{,}208$)	15 (14, 16; $n=2{,}640$)	1.8×10^{-25}	51 (49, 52; $n=2{,}944$)	46 (44, 48; $n=2{,}460$)	5.7×10^{-4}
Ownership and use of functional toilet with durable substructure	17 (16, 18; $n=3{,}214$)	2 (1, 2; $n=2{,}640$)	2.2×10^{-83}	2 (2, 3; $n=2{,}944$)	1 (1, 2; $n=2{,}460$)	1.6×10^{-3}
Ownership and use of durable toilet[a]	15 (14, 16; $n=3{,}214$)	1 (1, 2; $n=2{,}640$)	1.5×10^{-71}	2 (2, 3; $n=2{,}944$)	1 (1, 2; $n=2{,}460$)	5.1×10^{-4}
Ownership and use of unshared durable toilet[a]	5 (4, 6; $n=3{,}209$)	1 (0, 1; $n=2{,}640$)	4.8×10^{-24}	1 (0, 1; $n=2{,}944$)	0 (0, 1; $n=2{,}460$)	2.5×10^{-1}
Toilet ownership history						
Owns the same toilet since beginning	15 (14, 16; $n=3{,}206$)	12 (11, 13; $n=2{,}635$)	3.4×10^{-4}	43 (41, 44; $n=2{,}939$)	43 (41, 45; $n=2{,}452$)	8.4×10^{-1}
Owned a toilet that collapsed and rebuilt another	15 (14, 17; $n=3{,}206$)	8 (7, 10; $n=2{,}635$)	1.7×10^{-15}	20 (18, 21; $n=2{,}939$)	18 (16, 19; $n=2{,}452$)	4.8×10^{-2}
Used to own a toilet but no longer does	40 (38, 41; $n=3{,}206$)	54 (52, 56; $n=2{,}635$)	2.1×10^{-28}	25 (23, 26; $n=2{,}939$)	23 (21, 24; $n=2{,}452$)	1.2×10^{-1}
Has never owned a toilet	30 (28, 32; $n=3{,}206$)	26 (24, 27; $n=2{,}635$)	2.5×10^{-4}	13 (12, 14; $n=2{,}939$)	17 (15, 18; $n=2{,}452$)	1.6×10^{-4}
Toilet type (among those owning a toilet)						
VIP or KVIP latrine with concrete or plastic slab	60 (57, 63; $n=984$)	18 (15, 21; $n=541$)	3.0×10^{-55}	13 (11, 14; $n=2{,}045$)	8 (7, 10; $n=1{,}649$)	5.0×10^{-6}
Pit latrine with wood or mud platform	38 (35, 42; $n=984$)	82 (78, 85; $n=541$)	2.7×10^{-58}	86 (85, 88; $n=2{,}045$)	90 (89, 92; $n=1{,}649$)	2.1×10^{-4}
Pit latrine with no slab or platform	0 (0, 1;$n=984$)	0 (0, 1; $n=541$)	3.4×10^{-1}	1 (0, 1; $n=2{,}045$)	1 (1, 2; $n=1{,}649$)	3.1×10^{-2}
Pit lining (among those owning a toilet)						
Concrete, stones, or plastic	58 (55, 61; $n=982$)	9 (7, 11; $n=541$)	2.1×10^{-77}	4 (3, 5; $n=2{,}045$)	2 (1, 3; $n=1{,}649$)	8.9×10^{-4}
Mud lined with cement plastering	2 (1, 3; $n=982$)	1 (0, 2; $n=541$)	1.2×10^{-1}	2 (1, 3; $n=2{,}045{,}045$)	0 (0, 1; $n=1{,}649$)	9.2×10^{-5}
No lining	40 (37, 43; $n=982$)	89 (86, 92; $n=541$)	1.3×10^{-78}	94 (93, 95; $n=2{,}045{,}045$)	98 (97, 98; $n=1{,}649{,}649$)	1.7×10^{-7}
Toilet floor (among those owning a toilet)						
Concrete	48 (45, 51; $n=983$)	18 (15, 21; $n=541$)	1.1×10^{-31}	5 (4, 6; $n=2{,}043$)	2 (2, 3; $n=1{,}649$)	2.3×10^{-5}
Plastic	13 (11, 15; $n=983$)	0 (0, 1; $n=541$)	4.2×10^{-18}	0 (0, 0; $n=2{,}043$)	0 (0, 0; $n=1{,}649$)	—
Wood and mud plastered with cement	10 (8, 12; $n=983$)	27 (24, 31; $n=541$)	1.1×10^{-17}	17 (15, 18; $n=2{,}043$)	24 (22, 27; $n=1{,}649$)	5.7×10^{-9}
Wood and mud plastered with cow dung	9 (8, 11; $n=983$)	18 (15, 21; $n=541$)	4.5×10^{-6}	12 (10, 13; $n=2{,}043$)	8 (7, 10; $n=1{,}649$)	3.0×10^{-4}
Wood and mud with no plastering	16 (14, 18; $n=983$)	30 (27, 35; $n=541$)	2.2×10^{-11}	51 (49, 53; $n=2{,}043$)	54 (51, 56; $n=1{,}649$)	1.2×10^{-1}
Mud only	3 (2, 4; $n=983$)	6 (4, 9; $n=541$)	3.1×10^{-3}	9 (8, 10; $n=2{,}043$)	2 (1, 3; $n=1{,}649$)	1.7×10^{-19}
Toilet walls (among those owning a toilet)						
Concrete, bricks, or stones	17 (15, 19; $n=985$)	11 (8, 14; $n=541$)	1.8×10^{-3}	7 (6, 8; $n=1{,}932$)	2 (2, 3; $n=1{,}569$)	8.0×10^{-10}
Wood or bamboo	3 (2, 5; $n=985$)	3 (1, 4; $n=541$)	5.7×10^{-1}	3 (3, 4; $n=1{,}932$)	4 (3, 5; $n=1{,}569$)	5.8×10^{-1}
Metal sheet walls	1 (1, 2; $n=985$)	0 (0, 1; $n=541$)	1.2×10^{-2}	1 (0, 1; $n=1{,}932$)	1 (1, 2; $n=1{,}569$)	2.5×10^{-1}
Mud with cement plastering	18 (15, 20; $n=985$)	10 (8, 13; $n=541$)	2.2×10^{-4}	6 (5, 7; $n=1{,}932$)	7 (6, 8; $n=1{,}569$)	1.8×10^{-1}
Mud with cow dung plastering	47 (44, 50; $n=985$)	57 (52, 61; $n=541$)	3.8×10^{-4}	52 (50, 55; $n=1{,}932$)	55 (53, 58; $n=1{,}569$)	9.2×10^{-2}
Mud with no plastering	14 (12, 16; $n=985$)	20 (16, 23; $n=541$)	5.5×10^{-3}	31 (29, 33; $n=1{,}932$)	31 (28, 33; $n=1{,}596$)	8.4×10^{-1}
Toilet roof (among those owning a toilet)						
Thatch/grass	37 (34, 40; $n=985$)	40 (36, 44; $n=541$)	2.5×10^{-1}	59 (56, 61; $n=2{,}045$)	49 (47, 52; $n=1{,}649$)	6.7×10^{-9}
Metal sheet roof	49 (46, 53; $n=985$)	34 (30, 39; $n=541$)	2.0×10^{-8}	20 (19, 22; $n=2{,}045$)	26 (24, 28; $n=1{,}649$)	1.2×10^{-4}
Other	1 (0, 2; $n=985$)	0 (0, 1; $n=541$)	2.4×10^{-1}	1 (1, 2; $n=2{,}045$)	1 (0, 1; $n=1{,}649$)	1.1×10^{-1}
No roof	13 (11, 15; $n=985$)	25 (22, 29; $n=541$)	8.8×10^{-10}	20 (18, 21; $n=2{,}045$)	24 (22, 27; $n=1{,}649$)	2.7×10^{-4}

Table 4. (*Continued.*)

Indicator	Endline			Baseline		
	Subsidy communities	Control communities	*p*-Value	Subsidy communities	Control communities	*p*-Value
Households practicing OD as primary behavior (at home)[a]	54 (52, 55; $n = 3{,}160$)	69 (67, 71; $n = 2{,}589$)	2.0×10^{-32}	25 (23, 27; $n = 2{,}833$)	25 (23, 26; $n = 2{,}400$)	9.1×10^{-1}
Households with any member practicing OD at least sometimes (at home)	58 (56, 60; $n = 3{,}164$)	71 (69, 73; $n = 2{,}595$)	6.2×10^{-25}	33 (31, 35; $n = 2{,}849$)	33 (31, 34; $n = 2{,}391$)	8.8×10^{-1}
Households with observable feces around the premises	11 (10, 13; $n = 1{,}940$)	12 (10, 13; $n = 1{,}688$)	8.4×10^{-1}	13 (12, 15; $n = 2{,}672$)	14 (13, 16; $n = 2{,}312$)	4.4×10^{-1}
Households sharing their toilet with other households among all those who own and use a toilet	65 (62, 68; $n = 900$)	63 (58, 67; $n = 503$)	4.5×10^{-1}	66 (63, 68; $n = 1{,}807$)	59 (56, 61; $n = 1{,}444$)	8.6×10^{-5}

Note: Baseline surveys occurred in March–June 2019, whereas endline surveys occurred in November 2020–March 2021 in Northern Ghana. Each proportion (%) is followed by its associated 95% CI and *n*-value in parentheses. The *p*-values reflect chi-square tests for differences between households in subsidy and control groups, and they are expressed in scientific notation due to extremely small values in many cases. —, not applicable; CI, confidence interval; KVIP, Kumasi ventilated improved pit; OD, open defecation; VIP, ventilated improved pit.

[a]These statistics are those used as indicators for our primary sanitation outcomes.

remain functional longer, improving the cost effectiveness of CLTS followed by the subsidy program relative to CLTS alone, but we do not have data to support this expectation.

Results

We conducted a cRCT to test the impact of a pilot targeted subsidy program implemented by UNICEF in rural, post-ODF communities of Tatale and Kpandai Districts in Northern Ghana. The program identified the most vulnerable households through community-based targeting, also known as community consultation, using predefined criteria and distributed vouchers to those households. Households could redeem vouchers with local artisans to install a durable toilet substructure.

We surveyed all households in the study communities, apart from the <1% who declined to participate or where no adults were available after three attempts. In total, we surveyed 5,615 households at baseline (3,054 subsidy, 2,561 control) and 5,863 at endline (3,222 subsidy, 2,641 control). Among endline households, 5,412 were present during both survey phases, whereas 451 were new households not present at baseline and who had, for example, migrated into communities or had split off from a baseline household. Of these new households, four had entered subsidy communities prior to beneficiary identification and were classified as voucher-eligible households (Figure 1). A total of 203 households surveyed at baseline were no longer present at endline, with 121 of these having moved away (Table 3). Given that our focus is primarily on endline outcomes after the subsidy program, the results include the 451 new endline households but not the 203 baseline households that were no longer present. During program implementation, 441 households (14%) were identified as voucher-eligible in subsidy communities, of whom 426 (97%) were identified and surveyed at endline. In control communities, the community consultation and verification process identified 324 voucher-eligible households (13%), with 317 (98%) surveyed at endline (Figure 1, Table 3).

Below, we describe key findings related to sanitation conditions and the impacts of the targeted subsidy program in study communities. We begin by reporting an overall decline in sanitation conditions. Then, we investigate our primary research objectives: estimating the subsidy program's impacts for voucher-eligible households and other (noneligible) households, followed by estimates of the program's cost effectiveness.

Deterioration in Sanitation Conditions over Time

Across all study communities, we saw sanitation conditions deteriorate substantially over the period from baseline to endline, which lasted 17–24 months, depending on the community. Communities had achieved ODF status 3–32 months before baseline, with a median of 15.4 months in subsidy communities and 16.0 months in control communities, meaning that our endline surveys were conducted 1.8–4.4 y after attaining ODF status, with a median of 3.0 y in both subsidy and control communities. Overall, across all study communities, the proportion of households practicing primary open defecation increased from 25% at baseline to 61% at endline, mirrored by a drop in functional toilet ownership and use from 60% to 24%. At both baseline and endline, 15% of households did not practice primary open defecation and did not own a functional toilet, meaning they were using shared toilets they did not own. Subsidy communities exhibited less deterioration than control communities. In subsidy communities, primary open defecation increased from 25% to only 54%, and functional toilet ownership and use fell from 62% to 28%. In comparison, primary open defecation in control communities increased from 25% to 69%, and functional toilet ownership and use declined from 59% to 19% ($p < 0.001$ when comparing with subsidy communities at endline; Figure 2, Table 4). Community-level outcomes, looking at typical functional toilet coverage in a given community rather than across the entire study population, were similar (Figure S3).

Although large gains occurred during previous CLTS interventions, sanitation conditions declined in most communities after ODF status was attained, prior to our baseline survey (Figure S4). On average, functional toilet ownership and use decreased by 20 percentage points annually from ODF achievement to baseline. From baseline to endline, this decline accelerated slightly to 23 percentage points annually in control communities while remaining similar at 19 points annually in subsidy communities.

The deterioration in our study area was often related to latrine collapse. At endline, 36% of households reported owning a toilet that was no longer usable, with 93% of these respondents saying their toilet's pit or superstructure had collapsed. Of the collapsed facilities that had been functional at baseline, 91% were nondurable pit latrines with squatting platforms of wood and mud, and 84% were in communities with sandy or unstable soil conditions.

Table 5. Sanitation characteristics of voucher-eligible and noneligible households in Northern Ghana, measured at baseline.

	Subsidy			Control		
Indicator	Voucher-eligible households	Noneligible households	p-Value	Voucher-eligible households	Noneligible households	p-Value
Open defecation (OD)						
Households practicing OD as primary behavior (at home)[a]	25 (21, 29; $n = 410$)	25 (23, 27; $n = 2,423$)	0.94	28 (23, 33; $n = 308$)	24 (22, 26; $n = 2,092$)	0.19
Households with any member practicing OD at least sometimes (at home)	33 (28, 38; $n = 412$)	33 (31, 35; $n = 2,437$)	1.0	36 (31, 42; $n = 306$)	32 (30, 34; $n = 2,085$)	0.16
Toilet coverage						
Ownership and use of functional toilet[a]	59 (54, 63; $n = 422$)	62 (60, 64; $n = 2,522$)	0.16	56 (51, 62; $n = 317$)	59 (57, 61; $n = 2,143$)	0.42
Lives in a compound where at least one household owns/co-owns a functional toilet	62 (58, 67; $n = 426$)	60 (58, 62; $n = 2,792$)	0.21	61 (56, 67; $n = 317$)	63 (61, 65; $n = 2,314$)	0.020
Previously owned latrine but no longer does	23 (19, 27; $n = 422$)	25 (23, 27; $n = 2,517$)	0.31	25 (20, 30; $n = 316$)	22 (21, 24; $n = 2,136$)	0.43
Has rebuilt a latrine after collapse	19 (15, 23; $n = 422$)	20 (18, 22; $n = 2,517$)	0.58	16 (12, 20; $n = 316$)	18 (16, 20; $n = 2,136$)	0.40
Toilet quality						
Ownership and use of durable toilet[a]	0 (0, 2; $n = 422$)	3 (2, 3; $n = 2,522$)	0.004	0 (0, 1; $n = 317$)	1 (1, 2; $n = 2,143$)	0.093
Ownership and use of unshared durable toilet[a]	0 (0, 2; $n = 422$)	1 (0, 1; $n = 2,522$)	0.38	0 (0, 1; $n = 317$)	0 (0, 1; $n = 2,143$)	0.46
Lives in a compound where at least one household owns a durable toilet	0 (0, 2; $n = 426$)	2 (2, 3; $n = 2,792$)	0.004	0 (0, 1; $n = 317$)	2 (1, 3; $n = 2,311$)	0.020
Toilet sharing						
Households sharing their toilet with other households among all those who own and use a toilet	59 (53, 65; $n = 246$)	67 (64, 69; $n = 1,561$)	0.030	49 (42, 57; $n = 179$)	60 (57, 63; $n = 1,265$)	0.007
Households co-owning their toilet among all those who own and use a toilet	54 (47, 60; $n = 247$)	60 (58, 63; $n = 1,570$)	0.064	40 (33, 47; $n = 179$)	53 (50, 56; $n = 1,266$)	0.0009
Median number of households reported to use toilets by those who own and use a toilet	2	2	—	1	2	—

Note: Baseline surveys occurred in March–June 2019. Each proportion (%) is followed by an associated 95% CI and n-value in parentheses. The p-values reflect chi-square tests to determine the statistical significance of differences between voucher-eligible and noneligible groups. —, not applicable; CI, confidence interval.
[a]These statistics are those used as indicators for our primary sanitation outcomes.

Overall Impacts of the Subsidy Program

In this subsection, we begin with the analysis of the subsidy program's effects on all community residents, whether they are subsidy recipients or not. For context, recall that ~14% of households were eligible to receive subsidy vouchers. We report effects on voucher-eligible and noneligible households separately in the following subsections.

We observed substantial differences in sanitation outcomes between subsidy and control communities at endline. In the subsidy group, 54% of households reported practicing primary open defecation at endline, compared with 69% of control households ($p < 0.001$; Figure 2, Table 4). In parallel, 28% of households in subsidy communities owned and used functional toilets at endline, compared with 19% of control households ($p < 0.001$). Similarly, 15% of households in subsidy communities owned and used durable toilets at endline, compared with 1% of control households ($p < 0.001$). However, only 5% of households in subsidy communities owned and used durable toilets that were not shared with others because toilet sharing was common in this context. Households often shared their facilities either with co-owners who contributed to toilet construction or with nonowners. Although the degree of co-ownership declined from baseline to endline, especially among voucher-eligible households in subsidy communities (Tables 5 and 6), the introduction of subsidized toilets did not substantially alter overall sharing practices. Of households owning and using functional toilets, 63% reported sharing with others at baseline, compared with 64% overall and 60% specifically among voucher-eligible households in subsidy communities at endline. Generally, although sanitation conditions declined for both groups when comparing baseline outcomes to endline, the subsidy program attenuated these declines in subsidy communities.

Program Impacts for Voucher-Eligible Households

Voucher-eligible households exhibited indicators of poverty and vulnerability more often than other households, with 77% of voucher-eligible households meeting at least one criterion of poverty or vulnerability at endline, compared with only 49% of noneligible households (see Table S3 for a summary of individual vulnerability indicators). However, in all communities at baseline and in control communities at endline, the open defecation practices and functional toilet ownership of voucher-eligible households did not differ substantially from noneligible households ($p = 0.9$ for primary open defecation; Figure 2, Table 5).

At endline, voucher-eligible households in subsidy communities had better sanitation outcomes compared with both voucher-eligible and noneligible households in control communities at endline. For example, 18% of voucher-eligible households in subsidy communities practiced primary open defecation and 70% owned and used durable toilets, whereas 68% of voucher-eligible households in control communities practiced primary open defecation and 0% owned and used durable toilets (all $p < 0.001$; Figure 2, Table 6).

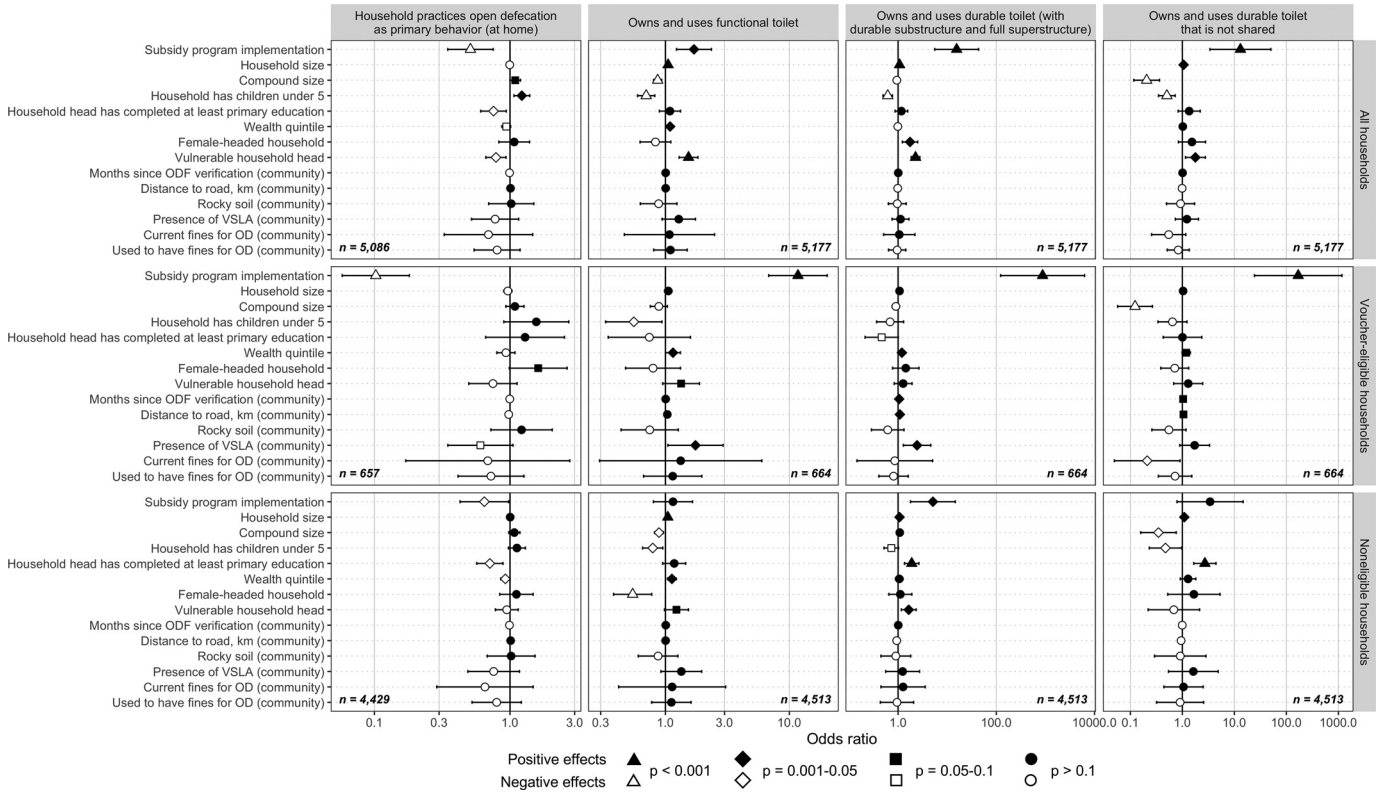

Figure 3. Results of household-level multivariate logistic regressions with adjusted standard errors to account for community clustering. Results use data from endline surveys, which occurred in November 2020–March 2021 in Northern Ghana. Each column of plots focuses on one of our primary sanitation outcomes at endline. Each row of plots focuses on specific sets of households (all households, only voucher-eligible households, and only noneligible households). Points represent ORs estimated using the multivariate logistic regression models with adjusted standard errors, and error bars represent 95% CIs of the ORs. The effect of the targeted subsidy program is shown by the first OR at the top of each graph ("subsidy program implementation"), with all covariates shown below. Any surveys with missing data associated with the outcomes or explanatory variables were excluded from the regression model, and the number of data points associated with each individual regression model is shown in the corresponding panel. Differences in *n*-values between primary open defecation and the other three outcomes are due to some respondents who did not report their primary defecation location. See Table S4 for all corresponding numerical results shown in this figure, including ORs, 95% CIs, and *p*-values associated with each OR derived using the regression models. Note: CI, confidence interval; OD, open defecation; ODF, open defecation-free; OR, odds ratio; VSLA, village savings and loan association.

Household-level multivariate regressions confirmed the subsidy program's positive effects for voucher-eligible households when controlling for several other factors that may also impact our sanitation outcomes (Figure 3; Table S4). For example, the subsidy program reduced the odds that a voucher-eligible household practiced primary open defecation at endline by 90% [OR = 0.10 (95% CI: 0.06, 0.18), $p < 0.001$]. With regard to unshared durable toilets, voucher-eligible households in larger compounds were less likely to own and use an unshared durable toilet [OR = 0.12 (95% CI: 0.06, 0.27) for a one-household increase in compound size, $p < 0.001$], given that in-compound sharing is more likely when compounds contain more households.

Voucher-eligible households in subsidy communities were also more satisfied with their toilets at endline. Of these households, 94% reported being satisfied or very satisfied with their facilities, whereas 58% of noneligible households in subsidy communities and 70% of all households in control communities reported being somewhat or very unsatisfied. Notably, despite these substantial impacts for voucher-eligible households in subsidy communities, 18% still practiced primary open defecation and 25% did not own and use a functional toilet at endline (Figure 2). Our tracking during program implementation showed all vouchers were redeemed, and 99% of respondents who reported receiving a voucher also reported constructing one of the three subsidized durable substructures (Table 3).

However, we found discrepancies between the voucher-eligible households that were identified during program implementation and the households that actually reported receiving vouchers during endline surveys. Of 426 voucher-eligible households at endline, 62 reported not receiving a voucher (15% exclusion rate; one additional household reported not knowing if they had received one), whereas 88 of 2,796 noneligible households did report receiving a voucher (3% leakage rate; Table 3). These discrepancies often involved a noneligible household receiving a voucher meant for an eligible household in the same compound. In 41 of 62 cases (66%), voucher-eligible households that did not report receiving vouchers lived in compounds where another household had reported receiving a voucher. Similarly, 55 (63%) of 88 noneligible households that reported receiving vouchers were in compounds with voucher-eligible households. Accordingly, for most discrepancies, the voucher was still received within the correct compound, but it went to a different household, either explicitly on behalf of the voucher-eligible household or due to some miscommunication.

Beyond this primary explanation, we were able to follow up with a few households over the phone to learn of other reasons for these discrepancies and make corrections to our data, if needed. We are not able to provide definitive numbers of households associated with the following situations because we were able to follow up with only a subset of households owing to limited cell phone coverage in this context. According to these follow-ups, some voucher-eligible households had actually received a voucher but had given it to another household, and then they reported not receiving one because they did not use it themselves. Households gave away vouchers if, for example, the vulnerable person

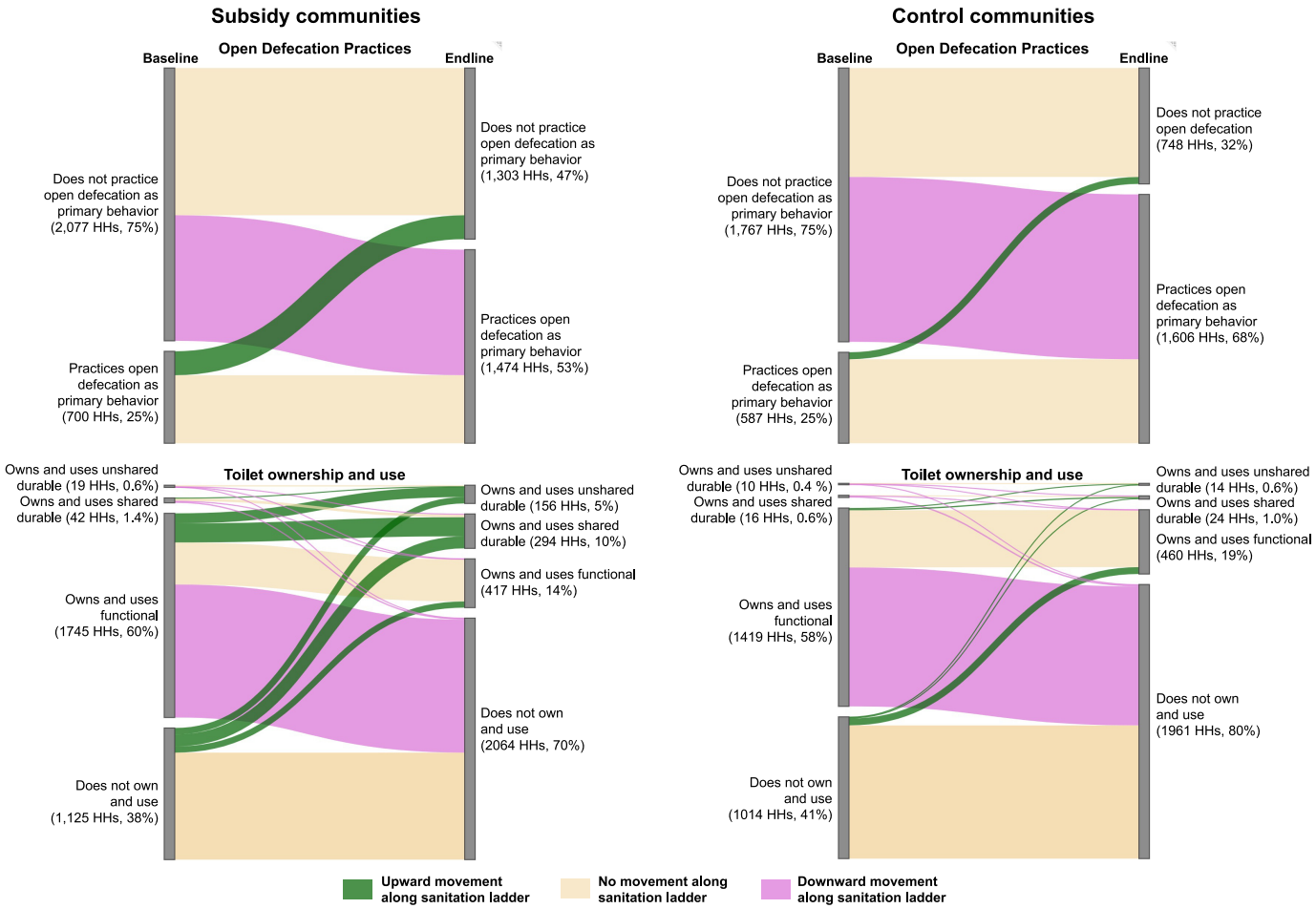

Figure 4. Changes in household (HH) sanitation outcomes at baseline and endline in subsidy (left) and control (right) groups. Baseline surveys occurred in March–June 2019, whereas endline surveys occurred in November 2020–March 2021 in Northern Ghana. The top set of Sankey diagrams shows changes in primary open defecation practices from baseline to endline, and the bottom set shows changes in toilet ownership and use. We differentiate between toilets classified as functional but not durable (labeled as functional here) and those classified as durable (which we portray as a higher level on the sanitation ladder). We also differentiate between ownership and use of shared durable toilets and ownership and use of unshared durable toilets. Upward flows from baseline to endline signify positive movement up the sanitation ladder (e.g., a household stops practicing primary open defecation, or a household transitions from owning and using a functional but not durable toilet to a durable one), whereas downward flows signify negative movement down the sanitation ladder. Static flows represent no change.

designated on the voucher had passed away. In other cases, the specific respondent at endline did not see themselves as "receiving" the voucher or "owning" the subsidized toilet if their household had received the voucher but another person in the household was the designated recipient. We rectified these instances in our final data set, classifying such households as having received a voucher. Finally, some noneligible households reported receiving a voucher and co-owning a subsidized toilet because they helped an eligible relative build the superstructure. Our data show that 18 (20%) of 88 noneligible households who reported receiving vouchers co-owned a durable toilet and therefore could fall into this category. Other noneligible households reported receiving a voucher that was for a close relative (e.g., a mother or brother) but who lived in a separate household. An additional 8% of voucher-eligible households in subsidy communities had received vouchers and installed durable toilets but were not yet using them at endline.

Program Impacts for Noneligible Households

We also observed some sanitation improvements among noneligible households, lessening the general increase in open defecation and slightly raising ownership and use of durable toilets. At endline, 59% of noneligible households in subsidy communities reported practicing primary open defecation compared with 69% in control communities, and 6% owned and used durable toilets in subsidy communities compared with 2% in control communities ($p < 0.001$). Multivariate household-level regressions showed that practicing primary open defecation at endline was less likely among noneligible households in subsidy communities compared with control [OR = 0.65 (95% CI: 0.43, 0.98), $p = 0.038$; Figure 3]. Although noneligible households in subsidy communities were not more likely than those in control communities to own and use a functional toilet at endline ($p = 0.5$), they were more likely to own and use a durable toilet [OR = 5.1 (95% CI: 1.8, 14.6), $p = 0.002$; Figure 3]. However, this difference in durable toilet ownership and use represents a relatively small increase from 3% at baseline to 6% at endline, some of which could have come from voucher leakage (Table 3).

Despite this limited effect on toilet ownership and use, we saw more substantial improvements in sanitation conditions among noneligible households at the compound level, due primarily to sharing of subsidized toilets. In subsidy communities, only 31% of noneligible households who lived in a compound with a voucher-eligible household practiced primary open defecation at endline, compared with 74% among the corresponding control group and 64% among noneligible households in subsidy communities living in compounds without voucher-eligible households (Figure S5, Table S5).

Table 6. Sanitation characteristics of voucher-eligible and noneligible households in Northern Ghana, measured at endline.

	Voucher-eligible households			Noneligible households		
Indicator	Subsidy communities	Control communities	p-Value	Subsidy communities	Control communities	p-Value
Open defecation (OD)						
Households practicing OD as primary behavior (at home)[a]	18 (15, 23; $n=423$)	68 (63, 73; $n=312$)	5.5×10^{-42}	59 (57, 61; $n=2{,}737$)	69 (67, 71; $n=2{,}277$)	2.1×10^{-13}
Households with any member practicing OD at least sometimes (at home)	25 (21, 30; $n=421$)	71 (66, 76; $n=312$)	7.3×10^{-35}	63 (61, 65; $n=2{,}743$)	71 (69, 73; $n=2{,}283$)	1.6×10^{-9}
Toilet coverage						
Ownership and use of functional toilet[a]	75 (71, 79; $n=426$)	21 (17, 26; $n=317$)	1.5×10^{-48}	21 (20, 23; $n=2{,}788$)	19 (17, 21; $n=2{,}323$)	5.1×10^{-2}
Lives in a compound where at least one household owns a functional toilet	92 (89, 95; $n=426$)	25 (21, 30; $n=317$)	9.4×10^{-79}	37 (35, 39; $n=2{,}788$)	26 (24, 28; $n=2{,}322$)	8.8×10^{-18}
Previously owned latrine but no longer does	9 (7, 12; $n=421$)	54 (49, 60; $n=317$)	6.2×10^{-41}	44 (42, 46; $n=2{,}785$)	54 (52, 56; $n=2{,}318$)	2.5×10^{-12}
Has rebuilt a latrine after collapse	47 (42, 52; $n=421$)	8 (5, 11; $n=317$)	1.5×10^{-30}	11 (9, 12; $n=2{,}785$)	9 (7, 10; $n=2{,}318$)	1.9×10^{-2}
Toilet quality						
Ownership and use of durable toilet[a]	70 (66, 74; $n=426$)	0 (0, 2; $n=317$)	1.6×10^{-81}	6 (5, 7; $n=2{,}788$)	2 (1, 2; $n=2{,}323$)	1.1×10^{-16}
Ownership and use of unshared durable toilet[a]	29 (24, 33; $n=422$)	0 (0, 2; $n=317$)	9×10^{-121}	2 (1, 2; $n=2{,}787$)	1 (0, 1; $n=2{,}323$)	8.8×10^{-1}
Lives in a compound where at least one household owns a durable toilet	84 (80, 87; $n=426$)	0 (0, 2; $n=317$)	3×10^{-112}	19 (17, 20; $n=2{,}788$)	2 (2, 3; $n=2{,}322$)	4.8×10^{-79}
Toilet sharing						
Households sharing their toilet with other households among all those who own and use a toilet	60 (54, 65; $n=316$)	62 (49, 74; $n=66$)	8.3×10^{-1}	67 (63, 71; $n=584$)	63 (58, 67; $n=437$)	1.3×10^{-1}
Households co-owning their toilet among all those who own and use a toilet	13 (9, 17; $n=321$)	42 (31, 55; $n=66$)	2.8×10^{-8}	42 (38, 46; $n=593$)	39 (34, 44; $n=442$)	3.2×10^{-1}
Median number of households reported to use toilets by those who own and use a toilet	2	2	—	2	2	—
Receipt of vouchers						
Reported receiving a voucher	85 (82, 89; $n=425$)	—	—	3 (3, 4; $n=2{,}789$)	—	—
Lives in a compound where at least one household reported receiving a voucher	95 (92, 97; $n=425$)	—	—	17 (16, 19; $n=2{,}788$)	—	—

Note: Endline surveys occurred in November 2020–March 2021. Each proportion (%) is followed by an associated 95% CI and n-value in parentheses. The p-values reflect chi-square tests to determine the statistical significance of differences between households in subsidy and control communities, and these values are expressed in scientific notation due to the extremely small value in many cases. —, not applicable; CI, confidence interval.
[a]These statistics are those used as indicators for our primary sanitation outcomes.

Given the importance of in-compound sharing, we also performed logistic regressions focused on compound-level toilet access, enabling us to determine whether the subsidy program affected compounds without voucher-eligible households (Figure S6, Table S6). Similar to our household-level results, we found essentially no impact on functional toilet ownership and use in compounds without voucher-eligible households ($p=1.0$), although a small effect on durable toilet ownership and use may exist ($p=0.049$). In subsidy communities, 49 compounds without voucher-eligible households (3.5%) improved from no toilets or nondurable toilets at baseline to durable toilets at endline, representing new durable installations or upgrades. However, up to 33 of these instances could be explained by program leakage, where noneligible households living in compounds without voucher-eligible households reported receiving a voucher. This leaves at least 16 compounds that may have installed durable toilets without vouchers, which aligns with reports from artisans, who recalled building 20 durable toilets for noneligible households in subsidy communities.

Our household- and compound-level regressions also identified other factors associated with sanitation outcomes, which are especially apparent for noneligible households (Figure 3). For example, noneligible households where the household head had completed at least primary education were more likely to own and use durable toilets ($p<0.001$) and less likely to practice primary open defecation ($p=0.003$). Similarly, noneligible households in higher wealth quintiles, which were estimated based on reported asset ownership,[46] were more likely to own and use functional toilets ($p=0.004$) and less likely to open defecate ($p=0.048$). In addition, noneligible female-headed households owned and used functional toilets less commonly ($p<0.001$). Female-headed households tended to be less wealthy, with 78% in the bottom two wealth quintiles, and at endline 50% of these households reported never having owned

a toilet. Finally, compounds without voucher-eligible households tended to have functional toilets less often in communities with rocky soils ($p = 0.040$), where pit construction may require costlier equipment or skilled labor, but more often when VSLAs were present ($p = 0.027$). VSLA leaders noted some members had used VSLA loans to install or improve toilets, but these facilities were typically nondurable and collapsed during rainy seasons.

Cost Effectiveness of the Program

As reported previously,[42] the cost of the subsidy itself ranged from 103 to 135 USD, depending on technology and location, and averaged 120 USD per beneficiary household. Subsidy program implementation and management costs averaged 148 USD per beneficiary household, resulting in an overall total of 268 USD.[42] We estimated that this total could drop to ~209 USD per beneficiary household if the program were implemented at a larger scale, depending on the degree to which implementation cost efficiencies could be realized.

To evaluate the costs of the subsidy program relative to its impact, we considered the degree to which the program *a*) reduced primary open defecation and *b*) led to upgrades from ownership and use of functional, nondurable toilets to durable toilets, calculating the changes in these outcomes from baseline to endline in subsidy communities relative to control communities (Figure 4). We estimate that the program resulted in *a*) 15% of households who went from practicing primary open defecation at baseline to using a toilet at endline and who would otherwise have continued open defecation, based on control communities; and *b*) 8% of households upgrading from ownership and use of nondurable toilets to durable toilets in subsidy communities compared with control. Note that this second group of households were already using toilets at baseline and therefore do not overlap with the previous category. The two groups together result in a total of 722 benefitting households (23%). This total corresponds to a cost of 128–164 USD per benefitting household. This range encompasses actual pilot costs and our at-scale estimates, given that we do not know the degree to which cost reductions and program benefits will be realized at scale.

Because this subsidy program is unlikely to be implemented apart from CLTS, it is critical to understand the cost effectiveness of CLTS followed by the subsidy program, compared with that of CLTS alone. In our assessment, we compared the net improvements of CLTS alone, represented by control communities from before CLTS to endline, with those of CLTS followed by the subsidy program, represented by subsidy communities. Compared with CLTS alone, the addition of the subsidy program resulted in net improvements for 64% more households that no longer practiced primary open defecation or upgraded from a nondurable to a durable toilet. However, CLTS followed by subsidies cost 129–147 USD per benefitting household, compared with 107 USD for CLTS alone—an increase of 21–37% (Figure S7).

Discussion

Deteriorating Sanitation Conditions

The post-ODF declines we observed in Northern Ghana were larger than most prior estimates of reversion to open defecation in sub-Saharan Africa, Asia, and the Pacific Islands.[4,11,14,18–26] At a maximum, previous studies have found up to 57% of households not using latrines in formerly ODF communities,[19] although such figures usually relied on limited data.[4,44] We found substantial evidence that deterioration was related to the collapse of nondurable toilets with no pit lining, especially when those toilets were located in areas with unstable soils. Collapse has also been found to be common in numerous other contexts such as Bangladesh, Malawi, and Mozambique, sometimes due to heavy rains and flooding.[21,47,48] Further analysis of the sanitation declines observed in our study, particularly with regard to the time period from ODF attainment to our baseline surveys, can be found in Delaire et al.[44]

Attenuating Declines through Targeted Subsidies

The deteriorating sanitation conditions seen in this context after ODF achievement suggest a need for additional or alternative approaches beyond CLTS alone, to sustain sanitation improvements and minimize latrine collapse. The targeted subsidy program evaluated here helped to attenuate sanitation declines, especially for voucher-eligible households and for noneligible households who were sharing subsidized toilets within their compounds. Improvements in subsidy communities relative to control are comparable with those resulting from the targeted subsidy trial in Bangladesh. In contrast to the program evaluated in our study, which provided subsidies after ODF achievement, the Bangladesh trial offered discount vouchers to 25–75% of eligible households (who represented 75% of the total population) covering 75% of total hardware costs during implementation of a program similar to CLTS. That program reduced open defecation by 9 percentage points and increased latrine coverage by 7 percentage points relative to communities that received the CLTS-like program alone.[35] Similarly, we observed that primary open defecation was 15 percentage points lower among households in subsidy communities compared with those in control communities at endline, whereas functional toilet coverage was 9 percentage points higher.

A large portion of the improvements we observed in our study resulted from households that were identified as voucher-eligible through community consultation. This identification process effectively identified households with certain vulnerabilities, as it was designed to do, but these vulnerabilities did not necessarily align with inequities specific to sanitation, given that baseline sanitation conditions were similar among voucher-eligible and noneligible households. Among these voucher-eligible households in subsidy communities, we observed absolute improvements in sanitation outcomes, contrary to the overall deterioration in sanitation conditions from baseline to endline (Figure 2). The subsidy program made it much less likely for voucher-eligible households to practice primary open defecation and more likely to own and use functional and durable toilets, as well as to own and use unshared durable toilets at endline, compared with those in control communities. Similarly, in Lao PDR, household-level pro-poor incentives for toilet construction improved sanitation outcomes among the poor, whereas village-level incentives not focused on poor households increased toilet coverage primarily among the nonpoor.[40]

We also saw some effects among noneligible households. Primarily, these impacts came from in-compound toilet sharing, which is consistent with trends across Ghana, where nearly half of the national population uses shared sanitation facilities.[49] Accordingly, a large portion of the subsidy program's impact on open defecation among noneligible households was due to sharing of subsidized toilets, made possible by their close associations with voucher-eligible households via settlement patterns. However, our results indicate that few compounds with no voucher-eligible households installed durable toilets, and a fraction of those that did may have done so via program leakage, where noneligible households received vouchers. Even including this potential leakage, durable toilet ownership and use among noneligible households in subsidy communities was only 4 percentage points higher than among the same group in control

communities at endline. For comparison, the subsidy trial in Bangladesh found that unsubsidized households increased their individual ownership of hygienic latrines with a sealed pit and intact slab by 8.5 percentage points and that increases in latrine access and use were more prominent when a greater fraction of a household's neighbors received subsidies, due to positive demand spillovers.[35]

Cost Effectiveness of Targeted Subsidies

Our cost-effectiveness analysis suggested that implementing this subsidy program after CLTS may contribute to maintaining and improving on the benefits of CLTS alone, although at a somewhat higher cost. A previous hypothetical benefit–cost study comparing these two scenarios[41] estimated the combination to be more cost effective than CLTS alone, although that study could not integrate actual program impacts or the overall sanitation decline, which were not yet known. In addition, that study focused on health benefits, including positive externalities associated with high levels of community sanitation coverage,[41] whereas we focused on benefits in sanitation outcomes. Notably, we included two categories of benefits in our analysis, representing households no longer practicing open defecation and those upgrading from nondurable to durable toilets. If our analysis had only included new ownership and use of durable toilets, CLTS followed by subsidies would have been more cost effective than CLTS alone because of the extremely low numbers of durable toilets in control communities. Furthermore, over time, we expect this comparison with CLTS alone would become more favorable for the subsidy program because subsidized durable toilets will likely remain functional longer than control communities' nondurable facilities, thereby sustaining the program's benefits.

However, beyond financial costs, the program also required numerous transactions between various actors, including DA facilitators, households, artisans, material suppliers, and financial institutions. It also lacked incentives for District officials to verify completed toilets, delaying performance-based payments to artisans, who also experienced delays if households were slow to complete the toilet superstructure.[42] Providing local officials and financial institutions with performance-based incentives, such as bonuses when all subsidized toilets and payments are complete in a community, may help to address such issues.[42]

Study Limitations

It is important to note the risk of reporting bias when relying on surveys with reported sanitation outcomes.[50,51] We included cross-validation questions and direct toilet observations to minimize bias, but we do see indications toward reports of better sanitation conditions at baseline and worse conditions at endline, which would have made the deterioration in sanitation conditions appear larger than it truly was. For example, 15% of households at baseline reported that they had never owned a toilet, whereas 28% reported the same at endline (Table 4). Some of this increase (3 percentage points) was explained by new households surveyed only at endline, 66% of whom reported never owning a toilet. However, a 10-percentage point increase remained where we would expect no increase; households that reported never having owned a toilet at endline should have reported the same at baseline. Generally, these inconsistencies tended to relate to reports of toilet co-ownership, where multiple households contributed to facility construction. Those who reported never having owned a toilet at endline but who did own a functional toilet at baseline were more likely to report co-owning the baseline toilet: 82% of those reporting never having owned at endline reported co-ownership as opposed to single ownership at baseline, compared with 56% co-ownership among all who owned a toilet at baseline. Furthermore, we saw a general decrease in reports of co-ownership across all households from baseline to endline. At endline, 34% of those owning a functional toilet reported they co-owned the facility, compared with 56% at baseline. This decrease was especially large in subsidy communities (29 percentage points), although voucher-eligible households who reported single ownership of their subsidized toilets at endline accounted for much of this difference. After removing voucher-eligible households, the decline in co-ownership remained 5 percentage points higher in the subsidy group, suggesting some potential for additional bias in these communities.

Given this examination of inconsistencies in our survey data and information gathered from follow-up interviews among community leaders, a portion of the deterioration we observed may represent a reporting bias at baseline or endline (or both). At baseline, respondents may have been afraid to report not having toilets due to recent ODF achievement, and at endline, respondents may have hoped to benefit from subsidies by reporting poor sanitation conditions, especially in subsidy communities. However, some of the trends we found may also represent real shifts in toilet ownership, moving away from perceived or actual situations where multiple households co-own a toilet. This explanation is especially likely for voucher-eligible households with subsidized toilets, but it may also include other households. For example, co-owned toilets may have collapsed, and some households may have rebuilt new facilities that are no longer shared with others.

To account for any potential bias, we examined alternative scenarios in which we removed certain surveys where biases may have been most likely. These scenarios provided more conservative estimates of the sanitation decline than those we see in the full data set. Two key examples of alternative scenarios include *a*) removing all households where respondents reported never having owned a toilet at endline but reported something different at baseline, and *b*) removing households that met the previous condition and also reported co-owning a toilet at baseline but not owning at endline. This second scenario considered potential bias related specifically to the decline in reported co-ownership, although we note that in some cases, a co-owned toilet may have collapsed and either was not rebuilt at all or was no longer co-owned after being rebuilt. Combining the results from the trimmed data sets in these scenarios with those from the full data set, we estimated the true decline in functional toilet ownership to fall within the range of 29–36 percentage points, whereas we estimated the true increase in primary open defecation to be 33–36 percentage points from baseline to endline (Figure S8). Even in the most conservative scenarios, more than half of households practiced primary open defecation and less than half owned and used toilets at endline, suggesting that considerable deterioration still occurred alongside any reporting bias. Notably, accounting for any additional bias toward greater declines in subsidy communities resulted in better outcomes relative to the control group, including in our regression analyses. We used the full survey data set when assessing the program's impacts in previous sections, meaning that reported estimates of program effects may be conservative.

In addition, because of incomplete information during the community randomization process, we needed to make a few adjustments to subsidy and control groups once communities were visited during baseline, as described in the "Methods" section. We made these adjustments before program implementation, and we found that endline outcomes remained similar even if we based our analysis purely on the initial randomization without adjustments, meaning that some original "subsidy" communities did not receive the intervention, whereas some "control" communities did (Figure S9).

In addition, baseline surveys took place primarily during the rainy season (April–June), whereas endline occurred during the dry season (November–March). Generally, our local understanding suggests people are more likely to practice open defecation during dry seasons, whereas toilets are more likely to collapse during rainy seasons and to be rebuilt during dry seasons. If there were no deterioration, we might expect open defecation and functional toilet ownership to both be higher during the dry season, but functional toilet ownership and use was actually much lower at endline, which took place during the dry season. In addition, the increase in open defecation from baseline to endline was consistent with the decrease in functional toilet ownership and use, further suggesting that the observed deterioration is not due simply to seasonal fluctuations. Finally, endline surveys typically occurred <1 y after subsidized toilet construction, and we cannot say how long subsidized toilets will remain functional, although we expect them to last longer than nondurable toilets.

Moving Forward with Sanitation Subsidies

Generally, the targeted subsidy program evaluated here attenuated post-ODF sanitation declines across communities and resulted in absolute improvements for voucher-eligible households. However, beyond in-compound sharing, the program had minimal effects on increasing demand for durable toilets among noneligible households. This outcome may relate to broader economic challenges likely not alleviated by providing vouchers to only 14% of households. Generally, the Northern Region is one of Ghana's poorest areas.[52] Many households not eligible for vouchers were still poor, with 52% of households in the region falling below the national poverty line, compared with 26% nationally.[52] Accordingly, the durable toilet substructures were expensive compared with typical incomes, which average 190 USD per month among rural households in Northern Ghana.[52]

Realizing greater market impacts may require adjustments to the subsidy program approach. For example, targeting criteria more closely aligned with sanitation inequities may better address these disparities. Based on our regression results, households where the head is female or did not complete primary education tended to have poorer sanitation outcomes in this context. However, adjusting targeting criteria to specifically focus on existing sanitation behaviors or infrastructure may increase the risk that households with the means to adopt more durable facilities on their own avoid doing so, in an effort to benefit from subsidies. Alternatively, subsidizing a greater fraction of households, perhaps using a tiered approach in which the poorest and most vulnerable receive full subsidies, whereas additional households receive partial assistance, may lead to more active sanitation markets and could reduce the per household cost of program implementation. In Bangladesh, subsidizing 75% of households rather than 25% resulted in a "social multiplier" that made both subsidized and unsubsidized households more likely to own hygienic toilets.[35] Timing is also crucial, given that sanitation declines often happened quickly after ODF achievement.[44] Integrating the program into follow-up visits shortly after ODF attainment may be especially useful and provide opportunities to reduce implementation costs while also not interfering with the internal behavior change approach of CLTS to reach ODF status. Sustained follow-up is often a factor that reduces deterioration back to open defecation, although budgets for follow-up visits are often limited.[4,11,14,20,21,53–55]

Future research may help to determine the most effective criteria for identifying households to receive sanitation subsidies, as well as the optimal time to implement subsidies following ODF attainment, with the goal that subsidies would occur before large post-ODF declines while not coming too soon such that households are not yet ready to upgrade recently installed facilities. Such an approach may contribute to more sustainable outcomes and active sanitation markets in this context, benefitting efforts toward the goal of universal safe and sustainable sanitation for all, including the most vulnerable.

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