Encouraging stewardship of a common good: Experimental evidence from Kenya*

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ABSTRACT: We conducted a randomized evaluation of two approaches to improve community management of donated water treatment infrastructure in rural Kenya. The infrastructure studied is the chlorine dispenser. The chlorine dispenser is a classic common good in that chlorine is rival in consumption, yet it is not practical to restrict access to it. One hundred and four communities were randomly assigned to a free provision arm or one of four community financing arms. In the community financing arms, water source users were responsible for purchasing chlorine refills. In half of these, an upfront contribution to the cost of the dispenser was required prior to installation ("up-front payment" treatment); cross-cut with this was a "threat of removal" treatment, in which the dispenser was a portable model that could be removed if the community failed to stock it with chlorine. In free provision communities, permanent dispensers were installed and chlorine refills were provided at no cost. We find no effect of up-front payment on household chlorine usage three months after installation, nor on whether the dispenser contained chlorine at unannounced visits over a period of eleven months. In contrast, threat of removal led to a 20 percentage point increase in the probability that a dispenser was stocked relative to permanent community-financed dispensers, which were stocked 41% of the time. We estimate that in communities with free refills, enough doses were consumed to consistently treat everyone's drinking water. Households in threat of removal communities consumed 30% of the recommended doses and households in other communities consumed 20% of the recommended doses.

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1. Introduction

Examples of poorly maintained and dysfunctional public infrastructure are all too common in developing countries. As economic theory predicts, public and common goods provided by governments and donors often quickly fall into disrepair when their management is delegated to users. This problem is particularly pronounced in the water sector, which has seen rapid expansion of infrastructure motivated by the Millennium Development Goals. Data on functionality is scarce, but several studies of hand pumps, which account for 32% of improved water source users in Sub-Saharan Africa and are almost always managed by the community after construction, suggest that failure rates across Africa are high – ranging from a minimum of 10% in Madagascar to more than 60% in Cote d'Ivoire, the Democratic Republic of Congo, and Sierra Leone (WHO/UNICEF, 2011). Two independent studies suggest that, in Kenya, over a third of hand pumps have fallen into disrepair (*ibid.*; Miguel & Gugerty, 2005). These trends are consistent with economic theory that predicts a coordination failure when no individual's private incentive to maintain a common good is greater than their individual cost to take action, even if the social benefit of investing in maintenance would far outweigh the social costs. To complicate matters further, if users of the water source have self-control problems they might indefinitely delay dealing with a maintenance problem, even if they always intend to take care of it in the next period (Akerlof, 1991; Ariely and Wertenbroch, 2002).

Without effective local institutions to solve this collective action problem, for example through taxation and government management, providers and users of common pool resources rely on other strategies to increase the probability that a resource will be maintained. In the water sector, "participatory" approaches to managing water infrastructure investments have been advocated by the World Bank and USAID for over 30 years (Dworkin, 1982 and World Bank, 1980 as cited by Kleemeier, 2000). Such approaches are often assumed to generate a greater sense of ownership among users, which in turn is expected to improve sustainability (Kleemeier, 2000). Standard features of participatory rural water projects include holding meetings to explain the project before it begins and allow the community the right to refuse it; formation of a user committee with responsibilities related to construction, operations and maintenance; and a requirement that users contribute to the project's up-front capital cost (*ibid.*, Table 1).

However, there is little rigorous evidence to support the belief held by many policy makers and NGOs that participatory approaches improve community management of local infrastructure. The majority of the literature is based on case studies (see Prokopy, 2005 for examples), and attempts to quantify associations between participation and outcomes are plagued by omitted variable bias (the same communities that succeed at maintaining water infrastructure also succeed at participating) and measurement issues, given the complex and subjective nature participation and ownership (see for example Marks, Onda, and Davis, 2013; Marks and Davis, 2012; Whittington et al. 2009). Economists have generally been skeptical of the promise of participatory approaches (Mansuri and Rao, 2004; Platteau, 2008), and have provided models explaining why participatory approaches might even be detrimental if technical decisions are delegated to users rather than experts (Khwaja, 2004).

Participatory approaches could potentially affect the sustainability of infrastructure projects in four ways: 1) through their effects on which communities receive projects, and which projects are implemented (screening and targeting); 2) through psychological sunk cost or "ownership" effects due to the requirement that users contribute cash, labor or other resources toward the initial capital cost; 3) through a related but distinct participation or decision effect that comes from users' part in choosing which project, or whether any project, is undertaken; and 4) by building capacity among users that enables more effective long-term management of the infrastructure. Previous experimental work has investigated both screening and sunk cost effects in the context of individual demand for water treatment (Ashraf, Berry and Shapiro, 2010). While the screening effect of price was important in this context, the sunk cost effect was not. The effect of users' participation in decision-making was tested by Olken (2010), who found higher user satisfaction, knowledge, and reported willingness to contribute to projects selected through a direct plebiscite as opposed to a representative democratic process, with a much smaller impact on the type of project selected.

An alternative approach to improving the management of infrastructure projects is to directly manipulate the expected costs and benefits to users of contributing to the maintenance of the common good. Costs of cooperating could be reduced, for example, by raising a large sum at once rather than smaller amounts over time. Conversely, coercion or public shaming could be used to increase the costs of not cooperating. Both of these mechanisms are at play in the *harambee*, or community fund-raising meeting, a common approach to raising funds for capital investments in public infrastructure in Kenya. Ngau (1987) estimates that harambees financed 12% of all national capital formation from 1980-84. Barkan and Holmquist (1986) found that that 90% of 2075 residents surveyed in 7 Kenyan districts had participated at some point in a harambee. The widespread reliance on the harambee system in Kenya suggests that it is possible for communities to cooperate, even if in many cases, such as failed water infrastructure, this is not a sufficient mechanism to ensure sustained service provision or infrastructure maintenance.

Raising funds for ongoing maintenance of donated or subsidized infrastructure, on the other hand, presents particular challenges. First, the fact that such infrastructure has been initiated and subsidized by an external actor implies that community demand for the infrastructure may be relatively weak. Second, as shown in a large number of laboratory experiments, contributions to public goods tend to fall over time in repeated games. Finally, the lack of a meaningful deadline by which operational funds must be raised (in contrast to the up-front contribution, which typically must be made by a deadline set by the donor) may lead users to procrastinate making a contribution indefinitely.

In this paper, we present the first rigorous test of the hypothesis that participation improves the management of community-managed infrastructure, alongside an alternative mechanism for catalyzing community contributions toward operational costs by preventing procrastination. These two approaches respectively reflect one of the most popular programmatic strategies for improving sustainability of investments in the water sector, and a new strategy that incorporates insights from behavioral economics about time inconsistency and the role of deadlines. We randomize communities into an *up-front payment* treatment, requiring an upfront contribution to the donated infrastructure which is small enough that it does not substantially screen out communities with low demand, and a *threat of removal* treatment in which the infrastructure is removed if it is not consistently maintained. We show that if individuals have time-inconsistent preferences, the threat of removing the infrastructure increases the expected cost of failing to raise the funds required for maintenance, and thus increases contributions.

We apply these two approaches to the terms under which a chlorine dispenser, a representative form of infrastructure that requires ongoing maintenance in the form of chlorine refills, is provided to rural communities in western Kenya. Access to safe water is an important global health challenge, and reflects one of the Millennium Development goals. Diarrheal diseases are estimated to have killed 810,000 children worldwide in 2010, accounting for 12% of under 5 deaths in Africa (Liu *et al.*, 2012), and the majority of this burden could be prevented through improvements in water, sanitation, and hygiene practices. Municipal chlorination of drinking water is widely used in the developed world and likely contributed to the two-thirds reduction in child mortality experienced in major US cities in the early 20th century (Cutler and Miller, 2005). In areas where piped water is not available, point-of-use chlorination is advocated by the US CDC (http://www.cdc.gov/safewater/), and has been shown to reduce diarrheal disease by roughly 30% (Arnold and Colford, 2007). Although chlorine is cheap to produce and distribute, available in many countries in the developing world, and relatively easy to use (requiring only the addition of one capful of the solution to a standard water collection container, followed by a 30 minute wait), take-up remains low. Fewer than 6% of households report to have chlorinated their drinking water in an analysis of 67 nationally representative surveys from developing countries (Rosa and Clasen, 2010). Based on evidence that the majority of households in rural western Kenya used chlorine when it was provided for free, and on the fact that packaging accounts for a large share of the costs of bottled chlorine sold in shops, the point-of-collection chlorine dispenser was invented as a more cost-effective means of providing access to water treatment (Kremer et al., 2011). Previous work has shown that chlorination rates in communities where a dispenser is installed are near 60%, over three times the status quo in the study area (*ibid*.).

The rest of the paper proceeds as follows. In the next section we present a simple model that helps formalize the mechanisms through which the up-front payment and threat of removal treatments could affect community members' decisions of whether or not to contribute to the maintenance of the infrastructure in a repeated game scenario. We then describe the chlorine dispenser and experimental treatments in more detail, and explain the data collection process. The results section documents the strength of the experimental treatments and their effects on household take-up of chlorination and maintenance of the dispenser. Finally, the discussion section summarizes the main findings of the study and contextualizes these within the broader literature.

2. Model

We consider whether individual i contributes fee f toward operation of the common good in period t. The individual's contribution is denoted by c_{it}, which may equal either 0 (does not contribute) or 1 (contributes). The sum of contributions from all individuals in period t determines whether the infrastructure will be operational in period $t+1$, with $o_t(f_{t-1}\sum_i c_{it-1}) = 1$ if sufficient funds are raised and $= 0$ otherwise. It is common knowledge that o_{t+1} is a weakly increasing function of c_{it}. The individual decides whether or not to contribute by comparing the utility value of f and the net present value of contributing.

Let $E_i[b_{t+1}]$ be the expected marginal benefit in period $t+1$ from contributions in the prior period. This value is equal to i's subjective change in the probability that the infrastructure will be functional due to her contribution, $p(o_{t+1} = 1)$ multiplied by her valuation of the private benefit from the infrastructure being operational $u_i(d_{t+1} = 1)$.

Assume that utility is linear in both cash and the benefits derived from the infrastructure, and that individuals have time inconsistent preferences as in Laibson's (1994) model of self-control problems, where β_i is the fixed discount factor by which all future periods are multiplied, and δ_i is the exponential discount factor. Under the status quo for infrastructure maintenance, o_t has no bearing on o_{t+1}, thus the decision of whether to contribute can be made separately each period. The individual contributes in period 0 if and only if:

$$-f + \beta \cdot \delta \cdot E[b_{t+1}] > 0 \tag{1}$$

Recalling the discussion above, participation may increase i's private valuation of the state of the infrastructure being operational by creating a feeling of "ownership", or it may lead to an increase in the subjective probability that her contribution is pivotal by increasing the community's fundraising capacity. Either of these impacts would increase the value of $E[b_{t+1}]$, thus increasing the likelihood that i contributes.

Under a threat of removal policy, the failure to raise operational funds results in permanent loss of access to the infrastructure: $o_t = 0 \Rightarrow o_{t+1} = 0$. The entire stream of future net benefits due to presence of the infrastructure thus factors into each period's decision of whether or not to contribute. In this case, the individual contributes in period 0 if and only if:

$$-f + \beta \cdot \delta \cdot E[b_1] + \beta \sum_{t=1}^{\infty} \delta^t \cdot (-f + \delta \cdot E[b_{t+1}]) > 0 \quad (2)$$

Because of time inconsistency in preferences, it is possible that:

$$(-f + \beta \cdot \delta \cdot E[b_1]) < 0, \quad (3)$$

such that the individual would not contribute in period 0 if the decision were made in isolation, but also that

$$-f + \delta \cdot E[b_{t+1}]) > 0, \quad (4)$$

such that the second term of inequality (2) is strictly positive.

If inequality (4) holds, that is, the expected net benefit up to period 1 of contributing in period 0 is negative, but the expected lifetime net benefit of contributing in all future periods is sufficiently large such that expression (2) is satisfied, that is, if

$$\beta \sum_{t=1}^{\infty} \delta^t \cdot (-f + \delta \cdot E[b_{t+1}]) > (f - \beta \cdot \delta \cdot E[b_1]), \quad (5)$$

then the threat of removal policy will increase contributions toward operational costs.

3. Methods

The Chlorine Dispenser

As shown in Figure 1, the point-of-collection chlorine dispenser comprises three essential components: a 3 L tank to hold the chlorine, a custom-made valve that dispenses exactly 3 mL per turn (enough to treat 20 L of water), and durable housing that protects the tank and valve and secures them into place at the water source. In this part of Kenya, households collect drinking water approximately every other day, typically in 20 L jerry-cans, so the dispenser holds enough chlorine to treat the all the drinking water used by a community of fifty households for roughly one month. The dispenser costs $120 to install, including the hardware, cement, and labor. Traditionally, dispensers are installed by inserting the housing into a cement base near the water source. We refer to this model as the "permanent" dispenser. For the purpose of this experiment, we adapted the design to allow removal of the dispenser. In the removable design, the dispenser housing is securely chained to hooks installed in the concrete base.

The NGO we worked with, Innovations for Poverty Action – Kenya, has installed over 1,500 dispensers. Under IPA's model, users of the water source are invited to a community meeting that begins with a discussion of diarrheal disease and chlorination as a method of prevention before describing the specifics of how to use the dispenser. Usage instructions are simple: rinse the water collection vessel, add a dose of chlorine, fill with water, agitate (generally accomplished during the walk home), and wait thirty minutes before drinking. Chlorinated water should be consumed or discarded within 48 hours, otherwise there may not be enough residual chlorine to ensure the water is safe to drink. Before the meeting is adjourned, the community selects a volunteer "promoter" who will take responsibility for refilling the tank when necessary and encouraging all community members to use the dispenser regularly for drinking water. Communities responsible for financing refills also select a fundraising committee of up to three members. The promoter and members of the fundraising committee receive additional training and t-shirts with the project logo in recognition of their important role in ensuring maintenance and use of the dispenser.

Study Setting

The study was conducted in rural Rachuonyo district of Kenya's Nyanza Province (see Figure 2). Residents of this area rely on communal water sources, primarily naturally occurring ones such as streams and springs, including for drinking water. The area is subject to water shortages and turbidity during the annual dry season and water quality at unprotected sources is poor year-round.

Identification of Water Sources

The timeline of study activities is shown in Figure 3. In June/July 2011, IPA staff worked with village elders to collect data on all point-source drinking water sources in rural parts of the district (excluding rivers, streams, lakes, and ponds which could be accessed by users at multiple locations). A total of 584 water sources were identified in this way.

IPA staff then visited the 228 of these sources that, based on village elders' reports, met the following criteria: water was available at the source year round, the water was never too turbid to drink, there were at least 20 households using the source during both the rainy and dry seasons, and users could use the source for free. At this visit, GPS data were collected, and the water source characteristics reported by the village elders were confirmed through observation and in consultation with households who lived near the source. A list of households using the source was generated through consultation with village elders and other water source users. Based on the confirmed eligibility criteria, plus an additional requirement that chosen sources must be at least 600m from the next nearest chosen source, 104 sources were selected for inclusion in the study, plus three back-up sources in case any of these should be found ineligible prior to treatment implementation.

Baseline Household Survey

In each community, 20 households were randomly selected from among the list of water source users identified during the previous visit to be interviewed. If it was not possible to connect with one of the sampled households by 1 pm on the day of the survey, a back-up household was chosen at random from among the remaining households. The baseline survey included sections on household demographics, water treatment behaviors, willingness to pay (WTP) for individually bottled chlorine, and a public goods game.

The methodology used to measure WTP was randomized at the individual level. In two thirds of the sample, willingness to pay was elicited using a take it or leave it (TIOLI) offer; for the remainder the Becker-DeGroot-Marshak method (1964) was used. Under our implementation of this mechanism, the participant was required to put the maximum amount of cash she was willing to pay on the table before the offer price was revealed. A randomly determined offer price was then revealed by opening a sealed envelope. The participant purchased the chlorine at the offer price if this was less than or equal to her maximum WTP. If her stated willingness to pay was less than the offer price, she was not allowed to purchase. This preference-revealing methodology is commonly used to estimate demand curves in experimental work (Lusk and Rousu, 2006).

At the time of the survey, individually-packaged 150 mL bottles of chlorine were widely available in shops in market towns (though not in most villages) for 20 Ksh ($0.25). Respondents were told that the maximum offer price they could get through this door-to-door promotion was 25 Ksh. There were five randomly-assigned offer prices: 5, 10, 15, 20, and 25 Ksh. Respondents played a practice round with a package of cookies before making their binding decision regarding the bottle of chlorine.

Experimental Treatment Arms

Sources were stratified by baseline mean willingness to pay for chlorine using data from those whose WTP was elicited using the BDM, [1] and randomized into the following five treatment arms, one in which chlorine was provided free of charge, and the remainder in which water users were responsible for purchasing refills:

T1, Free provision (12 water sources): a permanent dispenser was installed with no upfront contribution requirement. Free chlorine refills were delivered to the promoter by IPA staff as needed for the duration of study.

T2 & T4, Up-front payment (48 water sources): Water source users were invited to an initial meeting in December 2011. At this meeting, the chlorine dispenser was introduced, and those present were informed of the chance to obtain one at a highly subsidized price. Water source users were given three weeks to raise 1000 Ksh ($12.50) toward the cost of the dispenser infrastructure, and were encouraged to solicit contributions from as many of their number as possible. They were instructed to phone project staff at IPA to request their dispenser once at least 1000 Ksh had been collected. Purchase of chlorine refills was the responsibility of water users.

T3 & T4, Threat of removal (44 water sources): A portable dispenser rather than the permanent model was installed (Figure 1). Whereas permanent dispensers are cemented into the ground, the portable model rests on a tripod stand that can be securely chained and locked to a cement platform. Water users were informed that if the dispenser was found not to contain chlorine during an unannounced visit, IPA staff would remove the dispenser.[2] The first time the dispenser was found empty, water users would have one week to raise funds for a chlorine refill, upon receipt of which

[1] WTP data from this subset was used because it is not possible to aggregate binary data elicited using TIOLI offers with continuous data elicited using the BDM.

[2] See below for an explanation of the monitoring process.

by IPA the dispenser would be returned. Purchase of chlorine refills was the responsibility of water users.

T5, Comparison (22 water sources): Permanent dispensers were installed with no requirement of an up-front contribution from water users. Purchase of chlorine refills was the responsibility of water users.

Dispenser Installation

After the initially announced three-week deadline had passed, IPA staff periodically called community leaders at those sources that had not yet collected the 1,000 contribution, to encourage them to finish fundraising. After a grace period of an additional three weeks, dispensers were installed at all up-front payment treatment communities that had met the up-front contribution requirement, as well all other communities, were installed in January. In each community, a community meeting was held within three days of dispenser installation. At this meeting, instructions for how to use the dispenser were provided and the community selected the promoter. Except at the free provision (T1) sources, a committee was also selected to raise funds for the purchase of chlorine refills.

Chlorine Purchase Logistics

In each of the community financing arms (T2-T5), water users were provided with 2.5 L of chlorine on the day of dispenser installation. Thereafter, they were required to pay 200 Ksh ($2.50) for each 5 L refill of chlorine, which could be purchased from a network of 13 shops in the study area. These 5L refills were not sold elsewhere, although 150mL household-sized bottles of chlorine were widely available for 20 Ksh ($0.25); thus the costs of providing chlorine through the dispenser system to an entire community is roughly 30% the cost of the socially-marketed household alternative. Participating shops were provided with an initial supply of up to twenty 5L refill jugs (depending on how many dispensers they were expected to serve) and an initial payment of 300 Ksh ($3.75). Shopkeepers were asked to sell the refill jugs only at the specified price of 200 Ksh, and only to those presenting a study ID card. They were asked to record the number of jobs sold, and the water source number marked on the ID card of each purchaser, and to transmit this information to IPA each time a sale was made. When IPA staff next returned to restock the shop, the shopkeeper paid IPA 160 Ksh to replace each jug that had been sold and for which IPA had received SMS confirmation, thus providing the shop keeper a profit of 40 Ksh ($0.50) per jug. Upon successful completion of the project, shopkeepers were paid an additional 700 Ksh ($8.75) bonus, conditional on compliance with adherence to the terms of the agreement with IPA.

Data on Outcomes

A follow-up household survey was conducted in April 2012. The survey was carried out relatively soon after dispenser installation to maximize the ability to detect differences in household chlorine usage across treatment arms that did not stem from differences in chlorine refill purchases across communities. The survey included questions on households' contributions to the up-front and operational costs of the dispenser, the terms of the community's right to use the dispenser (what would happen if it were found empty), respondents' knowledge of how to use the dispenser, and the names of those on the fundraising committee. A test for residual chlorine was conducted on the household's stored drinking water to directly observe whether the water had been treated. In addition, the promoter and fundraising committee were interviewed separately, and the dispenser was checked to see if it contained chlorine.

A second source of outcome data comes from the records kept by shopkeepers. In addition to SMS messages recording sales, written records of chlorine refill sales were collected regularly from all participating shops during restocking visits by IPA staff.

Finally, for the first four months after dispenser installation, three community members were randomly selected from the list of households surveyed at baseline for a monitoring phone call to check on the functionality of the dispenser. If any of them reported that the dispenser was empty, this triggered an unannounced spot check visit by IPA staff. Additionally, ten dispensers were randomly selected each month for an unannounced spot check visit by IPA staff. Starting five months after dispenser installation, all dispensers were visited monthly for an unannounced spot check. In the analysis, we use only data from the second period, during which monthly spot checks were universal.

Empirical Approach

We use an intent-to-treat approach which includes all 104 communities participating in the study, regardless of whether they were able to raise the initial funds for dispenser installation (in the up-front payment arm) or whether their dispenser was removed at any point (in the threat of removal arm). We count such communities as having non-functional dispensers at all points in time when the dispenser is not present. The two communities that failed to raise the required funds for dispenser installation in the up-front payment arm were not included in the follow-up survey for budgetary reasons. In these communities, we estimate the household-level chlorine test results using the baseline self-reported chlorination rate in these two communities, scaled by the ratio of self-reported chlorination to positive chlorine tests in all other communities at follow-up.

4. Results

Sample Characteristics

Household- and community-level characteristics among the 2122 baseline survey respondents in 104 water sources and balance across treatment arms are shown in Table 1. The table shows that enumerators were almost always successful in interviewing females, who are more likely to make decisions about water. Respondents had seven years of education on average, and 70% of households included at least one child aged younger than five years. Social marketing of chlorine-based water treatment solution was very high in this area, with almost everyone reporting they had heard of the product. Thirty percent of respondents claimed they had treated the drinking water currently stored in the home. Self-reported chlorine usage in this part of Kenya is typically far higher than that verified by chlorine tests, hence this figure represents an upper bound of actual treatment rates.[3] Despite the relatively high reported levels of chlorination, the average willingness to pay for a bottle of chlorine through the promotion offered during the survey was less than half the commercial price. The sampled water sources were used by 40-50 households on average, fewer than half had an active committee to manage the water source prior to the study, and three-quarters of water sources included in the study were improved.[4] A joint test of equality of means shows that none of these characteristics differed significantly across arms.

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[3] No chlorine test was performed during the baseline survey. During the follow-up survey, chlorine was detected in the stored water of 50% of those who reported having treated it. While false negatives are possible, and more likely the longer water has been stored, social desirability and courtesy bias are also very likely.

[4] Improved sources are those that, by nature of their construction or through active intervention, are protected from outside contamination, particularly fecal matter. These include tube wells or boreholes, protected dug wells and

Confirmation of Treatment Implementation

We begin the analysis by confirming that the treatments were successfully implemented. As noted in Figure 3, all but two of the 48 communities randomized into the up-front payment treatment met the contribution threshold of 1000 Ksh and had a dispenser installed. Table 2 presents summary statistics on contribution outcomes in the up-front payment treatment based on data from contribution logs kept by dispenser fundraising committees. Histograms of the same outcomes are shown in Figure 4.[5]

The upper two panels of Figure 4 show that communities did indeed involve many users in the fundraising process, with the exception of one community where a single individual contributed the entire required amount. A number of communities raised more contributions than there were households on the list of users collected prior to the intervention. This could reflect contributions from multiple people in the same household, or some people contributing more than once, but it could also be an indication that user lists were not exhaustive despite our best attempts to enumerate all users for the sampling frame. In the lower two panels, we show the distribution of contributions. Fundraising committees typically collected small sums of money from many users; only one contribution exceeded 70 Ksh. Many communities raised more than the required amount, suggesting an additional channel through which the up-front payment treatment could have affected long term maintenance of the dispenser if the surplus funds were retained and used for refill purchases later.

We next establish that users at water sources in the threat of removal treatment understood this policy. In Table 3 (columns 1 and 2), we show that over half of the respondents in the surveyed communities did know the dispenser would be removed if the community did not pay for refills (the coefficient on the threat of removal treatment dummy plus the mean in the comparison group). Almost 30% of respondents in the comparison arm erroneously believed this to be true. The water sources included in the study were close enough together that it is possible they had heard this rule from a social contact who used one of the threat of removal treatment sources, but it is also possible

protected springs (natural springs around which a concrete casing has been constructed). Unimproved sources in our sample include unprotected springs and unprotected dug wells.

[5] Since contribution logs were not submitted by the two communities where no dispenser was installed, these are treated as having raised zero contributions. Two others raised the required amount but kept incomplete records; the recorded amount is used in the analysis.

that the survey enumerators were prompting respondents (they were instructed to ask this as an open-ended question and match the response to specific answer codes but they may have deviated from the protocol). It is also interesting to note that respondents in communities required to contribute to the cost of the dispenser up front were significantly less likely to think their dispenser would be removed, suggesting that this treatment was successful in generating a sense of ownership.

As discussed in Sections 1 and 2, the requirement that users contribute to the cost of the dispenser prior to installation could potentially have increased the capacity of water source users to raise funds through learning by doing. Further, either treatment could have affected the committee's motivation and thus level of activity. We examine the impact of both treatments on the ability of respondents in the follow-up survey to name a member of the fundraising committee survey as a proxy for the committee's effectiveness in columns 3 and 4 of Table 3.[6] Free provision water sources are excluded from this analysis, as no fundraising committee was associated with these sources, as is the one community in which no fundraising committee survey was completed, and the two up-front payment treatment communities that did not raise sufficient funds for a dispenser and were thus not included in the follow-up survey.[7] The up-front payment treatment appears to have increased the chance that respondents correctly named a member of the committee by between 6 and 8 percentage points relative to 30% in the comparison arm. The threat of removal treatment had no impact this outcome.

Of the 44 dispensers in the threat of removal arm, 18 were removed at some point during the 11 months of monitoring, the first one just two months after installation and the majority occurring five months after installation when the regular monthly spot-checks were initiated at all dispensers (Figure 5). When project staff removed a dispenser, they left a wooden sign in its place. The sign reiterated the terms of the agreement which had been explained at the initial community meeting: the dispenser had been removed because it was empty and the community had one week to purchase a refill or else IPA would not return the dispenser. The second time a dispenser was found

[6] Respondents were asked to list as many members of the committee as they could think of. These names were then matched to the name of the respondent to the fundraising committee survey conducted at the same time. Since only one of three members of the committee responded to fundraising committee survey, this yields a lower bound estimate of the proportion of water users who know the name of someone on the committee.
[7] Including these two communities reduces both the point estimate (to 5-6%) and significance (to p=0.22 in the version without controls and p=0.095 in the specification with controls) of the up-front payment treatment.

to be empty there was no possibility to reclaim it. Among the 18 dispensers that were removed, 5 were ever returned, one of which was subsequently removed permanently. Thus, a total of 30 of the 44 dispensers in the threat of removal treatment made it all the way through the study. Cumulatively, water users in the threat of removal treatment lost slightly more than 10% of their access to their dispensers over the year after installation (63 out of a possible 528 months).

Treatment Effects on Dispenser Knowledge and Chlorine Use

Table 4 presents the results on the effects of the treatments on dispenser knowledge, chlorine availability, and household level verified chlorine use at the time of the follow-up survey in April 2012. To the extent that the interventions had an impact on the engagement of water users, we would expect to see an impact on their knowledge of how to use the dispenser. Respondents to the follow-up survey were asked to describe the order in which the three steps of dispenser use should be carried out, as if they were explaining the procedure to a neighbor who had never used a dispenser. Overall, 80% of respondents answered this question correctly. Neither the up-front payment nor the threat of removal treatment had any impact on the proportion of correct answers (columns 1 and 2).[8]

It was expected that most communities would have succeeded in raising funds to stock dispensers up to the time of the follow-up survey, and that it would thus be possible to detect differences in chlorine use arising from household-level demand rather than community-level success at fundraising. As it turned out, 45% of dispensers were found empty. This included some from which the tank itself had been removed "to protect it", but could be accessed at the promoter's home. Columns 3 and 4 show that dispensers in threat of removal treatments were between 17 and 20 percentage points more likely to have chlorine in their tank on the day of the follow-up survey, relative to 46% of dispensers in the non- up-front payment, non-threat of removal treatment arm, though the statistical significance of this effect is marginal and only apparent when baseline controls are included. The point estimate of the effect of the up-front payment treatment is negative and close to zero. Availability of chlorine in the free delivery group is similar to that seen under threat of removal, although the small number of dispensers in this treatment limits the possibility for statistical inference.

[8] The two communities where no dispenser was installed are omitted from this analysis.

Greater availability of chlorine in the threat of removal treatment did not translate into higher chlorine usage, as measured in the follow-up household survey (columns 5 and 6). It is possible that the large point estimate of the effect of the threat of removal treatment on chlorine availability is a reflection that community members knew they were supposed to have a stocked dispenser and thus were simply complying with the terms of the treatment on the day of the survey.[9] Although the possibility of such bias casts some doubt on this result, it also implies that with strong monitoring, the threat of removal incentive could indeed be an effective strategy for promoting maintenance.

Table 5 confirms that the threat of removal treatment did indeed lead to better maintenance outcomes using the more objective measure of whether the dispenser contained chlorine at unannounced spot-check visits. Although spot-checks were performed monthly starting five months after installation, we restrict the analysis to only three months' worth of data since the intervening months are likely to be highly correlated and would not add much variation to the data. When pooling data from multiple months, we use a random effects model to control for unobserved community-level characteristics. Columns 1 and 2 show that the threat of removal treatment led to a 19-20 percentage point increase in the probability that dispensers were stocked over the course of the monitoring period. This effect grows stronger over time, reaching 26% by 11 months after dispenser installation. Once again, the up-front payment treatment had no effect on maintenance.

Finally, in Table 6, we consider the effect of the treatments on the number of refills purchased by each community. To account for heterogeneity in the number of users per water source, we scale the number of refills by the number of households using the source to arrive at a usage measure in terms of doses of chlorine per household. In the comparison arm, which received chlorine refills free of charge for the duration of the study, communities consumed enough refills to allow all users to treat their water approximately every other day over the course of the year (coefficient on comparison + excluded category mean = 162 + 40 = 182 ≈ 365/2). This is consistent with estimates

[9] Although the follow-up survey was intended to be unannounced, it was necessary to alert at least the village elder that the research team would be visiting the village, and it is quite likely that he would have notified the promoter who was responsible for refilling the dispenser. The enumerators who conducted the follow-up survey were distinct from the team of IPA staff who were conducting the monitoring of dispensers in the use-it-or-lose-it treatment. Unfortunately, due to a communication lapse when management on the project changed, dispensers in the use-it-or-lose-it treatment found to be empty on the day of the follow-up survey in April were not removed, as the protocol had specified. This oversight was corrected in June when monthly spot-check visits to all dispensers were implemented and the use-it-or-lose-it terms were regularly enforced for all 44 dispensers in that treatment.

that households collect one 20L jerry-can of water for drinking approximately every other day. Communities in the threat of removal treatment purchased roughly 60 doses per household, or about 30% of the amount they would need to consistently chlorinate their water. Communities in the up-front payment treatment purchased roughly 40 doses per household, or about 20% of the amount they would need to consistently chlorinate their water.

We also consider whether paying for chlorine refills would be optimal in each community if there were no free-rider problem, using the baseline data on willingness to pay for bottled chlorine. Bottled chlorine costs 20 Ksh for 150 mL (50 doses), so each dose costs 0.4 Ksh. Dispenser refills are 5 L (1666 doses) and cost 200 Ksh, so each dose from a dispenser costs 0.12 Ksh. If there were a way to restrict access to the dispenser such that users paid only the marginal cost of their dose (rather than also having to pay for free-riders or having to contribute to the up-front cost of the installation), 83% of households would be willing to pay the cost of dispenser use. In contrast, fewer than 20% of respondents who purchased a bottle of chlorine at the market price during the willingness-to-pay exercise . Of course, free-riding will occur, so we also consider how much free-riding could be afforded if those who were willing to pay for bottled chlorine paid the same price per dose at the dispenser (making them indifferent between the two delivery systems). Summing the difference between willingness to pay for bottled chlorine and the price per dose from a dispenser over all survey respondents for whom this difference was positive, we find that each community could afford 2.75 free-riders per year on average. Since even those whose willingness to pay for bottled chlorine is greater than the price per dose from a dispenser will also want to free-ride, despite the drastic difference in marginal cost between the two delivery systems, the potential surplus available through the dispenser system does not seem likely to be sufficient to handle the extent of free-riding that is likely to occur.

5. Discussion

Poorly maintained infrastructure is a common problem in developing countries, despite increased focus on improving the sustainability of government and donor investments. We present results from a randomized evaluation that tested a common programmatic approach (the up-front payment treatment, in which communities were required to make an upfront contribution toward the cost of the infrastructure) and a novel contract under which the infrastructure would be removed if it were not used. By setting the contribution requirement low, and allowing communities sufficient time to raise funds, we aimed to evaluate the effects of a participatory approach to provision of water infrastructure distinct from its potential effect of excluding communities without sufficiently high demand. The threat of removal treatment is based on the insight from behavioral economics that many people suffer from self-control problems, indefinitely postponing unpleasant tasks, and thereby worsening the collective action problem that arises when community members are required to cooperate to sustain provision of a common good.

The coordination failure in the case study used in this evaluation is substantial. Based on willingness to pay for an equivalent private good (individually-bottled chlorine), we find that there is substantial consumer surplus to be generated by switching to a community-level delivery system (the chlorine dispenser) – 82% of respondents would be willing to purchase a dose of chlorine at the dispenser whereas fewer than 20% would purchase at the market price for the private good. However, because the chlorine dispenser is non-excludable but the chlorine itself is rival, communities struggle to maintain cooperation.

Using a variety of measures, we demonstrate that the up-front payment treatment had no effect on individual-level usage of the infrastructure, nor on communities' ability to sustain cooperation over 11 months. The threat of removal treatment, on the other hand, was effective at improving maintenance of the common good. The mechanism through which a threat of removal contract could affect sustainability are consistent with the predictions of behavioral economic theory.

This type of contract are is not appropriate for all infrastructure – if the infrastructure cannot be moved or disabled (or if disabling infrastructure is not politically feasible) then it will not be possible to enforce the sort of contract we tested. Indeed, in the case of the particular infrastructure studied for this evaluation, the cost of implementing the threat of removal is not justified by its impact. Visits to rural water sources by program staff to monitor chlorine availability entail significant costs. The marginal cost of providing free chlorine refills during such visits is relatively minor, and has a large positive impact on chlorine use. However, there may be other common goods for which threat of removal contracts could help promote better maintenance. Finally, in cases where it is feasible to remove infrastructure from communities that do not use it, doing so could improve the efficiency of allocation.

References

Ariely, D and K Wertenbroch (2002), "Procrastination, Deadlines, and Performance: Self-control by Precommitment." *Psychological Science*, Vol. 13(3): 219-224.

Arnold, B and J Colford. 2007. "Treating Water with Chlorine at Point-of-Use_to Improve Water Quality and Reduce Child Diarrhea in Developing Countries: A systematic Review and Meta-Analysis." *American Journal of Tropical Medicine and Hygiene*. Vol. 76(2): 354-364.

Ashraf, N, J Berry, and J Shapiro. 2010. "Can Higher Prices Stimulate Product Use? Evidence from a Field Experiment in Zambia." *American Economic Review*. Vol. 100(5): 2383-2413.

Barkan, J and F Holmquist. 1986. "Politics and the Peasantry in Kenya: The Lessons of *Harambee*." Working paper no. 440, Institute for Development Studies. University of Nairobi; Nairobi, Kenya. http://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/1299/wp440-45939.pdf?sequence=1

Becker, G, M DeGroot, J Marshak. 1964. "Measuring Utility by a Single-Response Sequential Method." *Behavioral Science*. Vol. 9(3): 226-232.

Cutler, D and G Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." *Demography*. Vol. 42(1): 1-22.

Dworkin, D. 1982. *Community Water Supply in Developing Countries: Lessons from Experience*. AID Program Evaluation Report No. 7, United States Agency for International Development, Office of Evaluation, Washington, DC.

Khwaja, A. 2004. "Is Increasing Community Participation Always a Good Thing?" *Journal of the European Economic Association*. Vol. 2(2-3): 427-436.

Kleemeier, E. 2000. "The Impact of Participation on Sustainability: An Analysis of the Malawi Rural Piped Scheme Program." *World Development*. Vol. 28(5): 929-944.

Kremer, M, E Miguel, S Mullainathan, C Null, and A Zwane. 2011. "Social Engineering: Evidence from a Suite of Take-up Experiments in Kenya." Working paper available at http://elsa.berkeley.edu/~emiguel/pdfs/miguel_chlorinedispensers.pdf

Laibson, D. 1994. "Essays in Hyperbolic Discounting." Ph.D. dissertation, MIT.

Liu, L *et al.* 2012. "Global, Regional, and National Causes of Child Mortality: An Updated Systematic Analysis for 2010 with time trends since 2000." Lancet. Vol. 379: 2151-2161.

Jayson L. Lusk and Matthew Rousu (2006) "Chapter 2: Market Price Endogeneity and Accuracy of Value Elicitation Mechanisms" in *Using Experimental Methods in Environmental and Resource Economics*, John A. List, ed. Cheltenham, UK: 200 pp.

Mansuri, G and V Rao. 2004. "Community-Based and –Driven Development: A Critical Review." *The World Bank Research Observer*. Vol. 19(1): 1-39.

Marks, S, K Onda, and J Davis. 2013. "Does Sense of Ownership Matter for Rural Water System Sustainability? Evidence from Kenya." *Journal of Water, Sanitation, and Hygiene for Development*. Vol. 3(2): 122-133.

Marks, S and J Davis. 2012. "Does User Participation Lead to Sense of Ownership for Rural Water Systems? Evidence from Kenya." *World Development*. Vol. 40(8): 1569-1576.

Miguel, E and M Gugerty. 2005. "Ethnic Diversity, Social Sanctions, and Public Goods in Kenya." *Journal of Public Economics*. Vol. 89(11-12): 2325-2368.

Ngau, P. 1987. "Tensions in Empowerment: The Experience of the *Harambee* (Self-help) Movement in Kenya." *Economic Development and Cultural Change*. Vol. 35(3): 523-538.

Platteau, J. P. 2008. Pitfalls of participatory Development. United Nations. http://www. fundp. ac. be/pdf/publications/61702. pdf.

Rosa, G and T Clasen. 2010. "Estimating the Scope of Household Water Treatment in Low- and Medium-Income Countries." *American Journal of Tropical Medicine and Hygiene*. Vol. 82(2): 289-300.

Whittington, D et al. 2009. "How Well Is the Demand-Driven, Community Managed Model for Rural Water Supply Systems Doing? Evidence from Bolivia, Peru, and Ghana." *Water Policy*. Vol. 11(6): 696-718.

WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation. 2011. "Drinking Water: Equity, Safety, and Sustainability." http://www.wssinfo.org/fileadmin/user_upload/resources/report_wash_low.pdf

WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation. 2013. "Progress on Sanitation and Drinking-Water: 2013 Update." http://www.wssinfo.org/fileadmin/user_upload/resources/JMPreport2013.pdf

Wilson, L. 1992. "The *Harambee* Movement and Efficient Public Good Provision in Kenya." *Journal of Public Economics*. 48:1-19.

World Bank. 1980. *Water Supply and Waste Disposal*. Washington, DC: The World Bank.

Figure 1: The Chlorine Dispenser Hardware

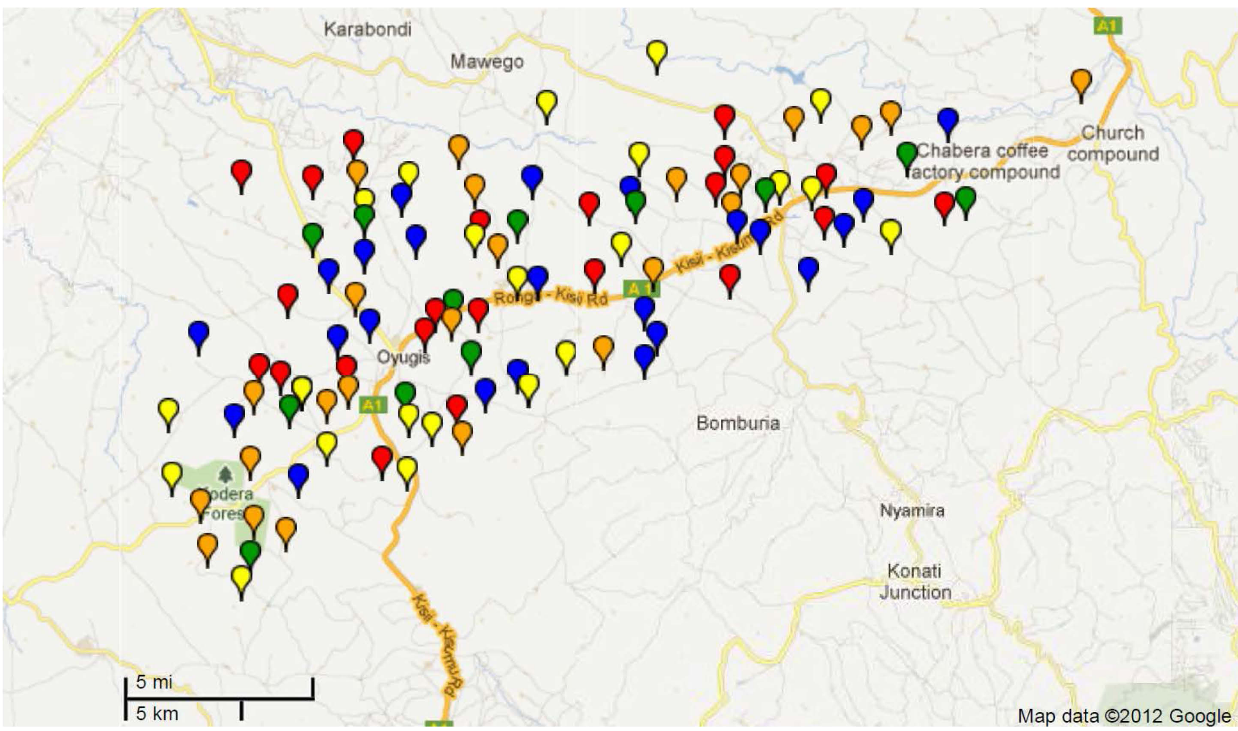
One turn of the dial dispenses exactly 3 mL of dilute sodium hypochlorite, enough to treat 20 L of non-turbid water (two doses are required for turbid water). The 3L tank thus holds enough chlorine to treat approximately one month's worth of drinking water for a community of 50 households.

Permanent dispensers are installed directly into a concrete base (left), whereas portable dispensers can be chained and locked securely to the concrete base (right).

Figure 2: Study and Water Source Locations

Panel A: Rachuonyo District

Panel B: Study Water Sources by Treatment Arm Map data ©2013 Google



Treatment arm legend: green = free delivery, blue = up-front payment only, red = threat of removal only, orange = up-front payment & threat of removal, yellow = comparison

Figure 3: Study Timeline

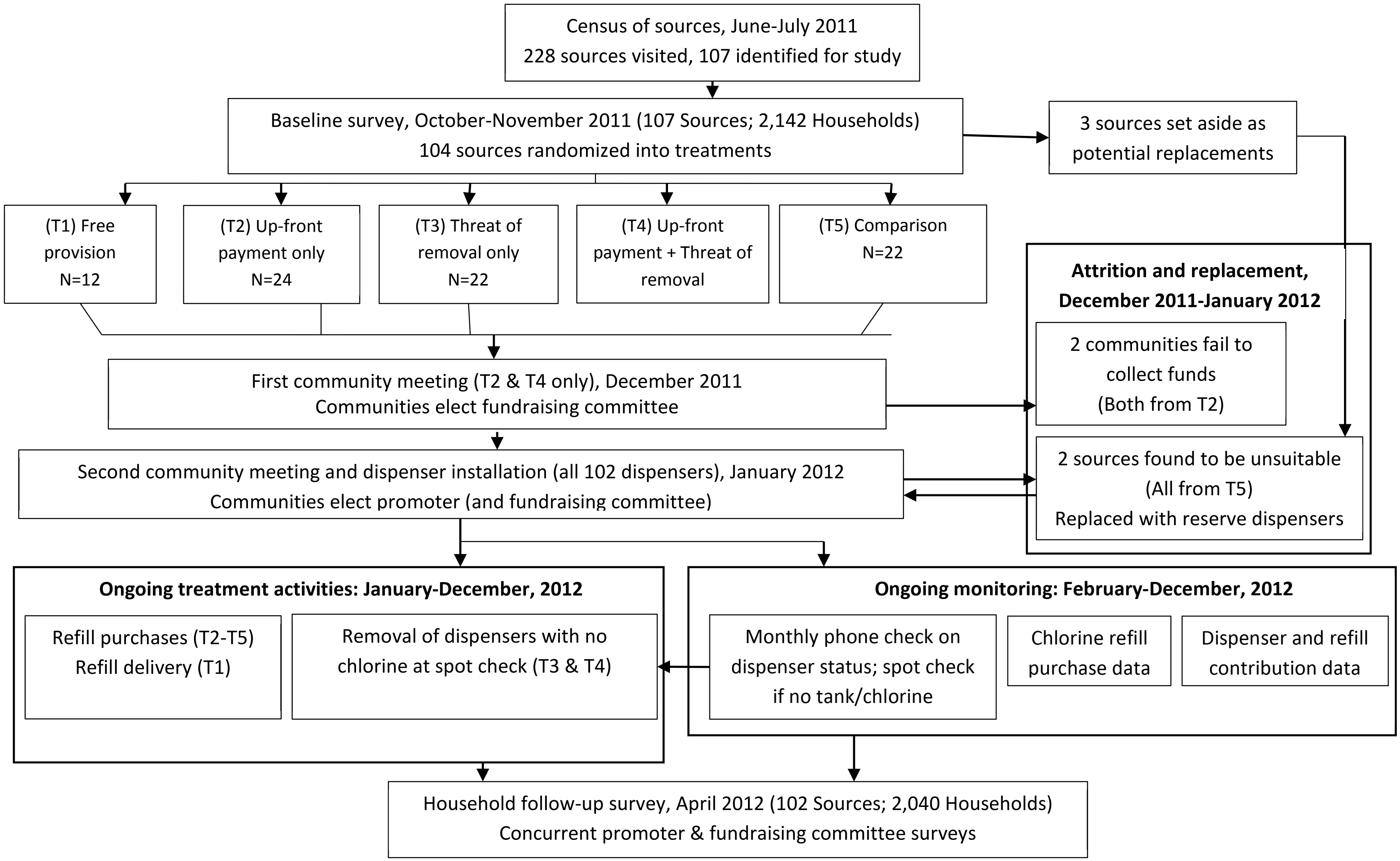
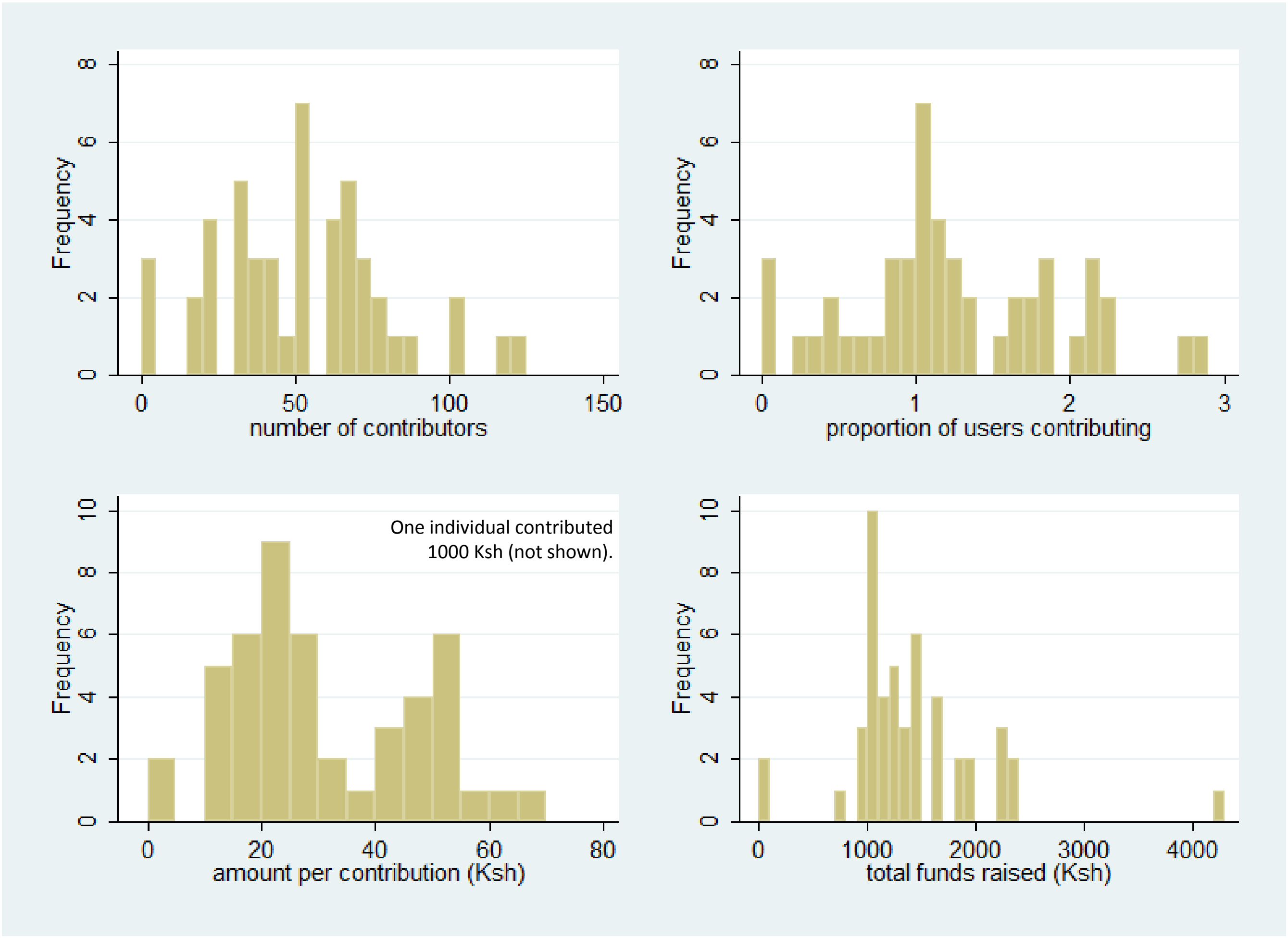


Figure 4: Contributions in Up-front payment treatment (T2 and T4)



Notes: Data is from fundraising committee logs; communities that did not raise the required contribution of 1000 Ksh did not submit logs and are shown as not having raised any contributions.

Figure 5: Removal and Return of Dispensers in the Threat of Removal Treatment (T3 and T4)

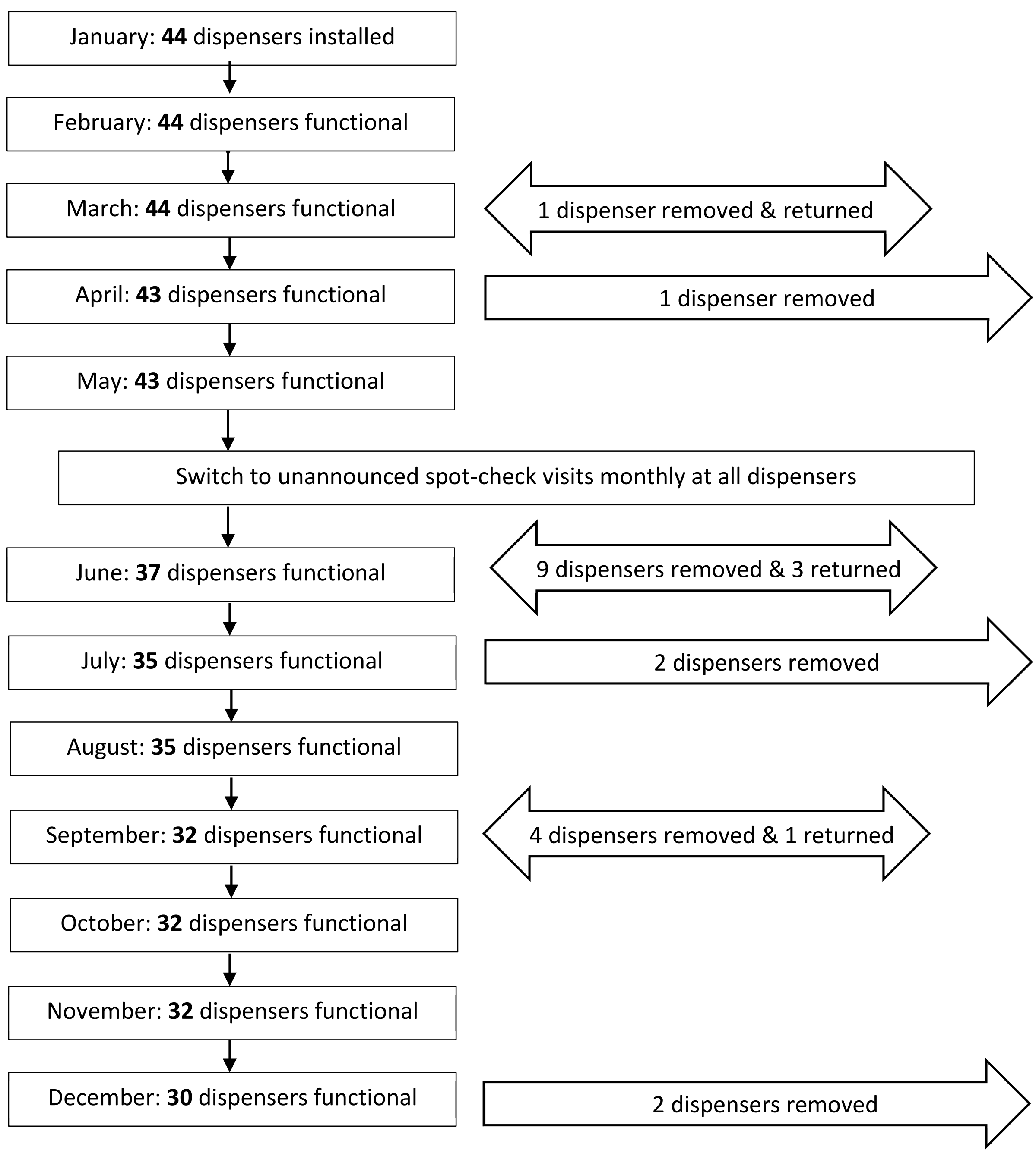


Table 1: Baseline controls and balance check

	T1	T2	T3	T4	T5		
	Free Provision	Up-front Payment	Threat of Removal	Up-front Payment + Threat of Removal	Comparison	Full Sample	P-value for equality of means
Household-level variables:							
Respondent is female	1.00	0.98	0.99	0.98	0.99	0.99	0.393
Respondent education (years)	7.08	7.16	7.03	6.98	6.83	7.01	0.614
Household has children under 5	0.71	0.74	0.69	0.71	0.68	0.70	0.303
Respondent heard of WG or similar	0.99	0.98	0.99	0.98	0.99	0.99	0.235
Drinking water reported treated at baseline	0.30	0.31	0.28	0.29	0.33	0.30	0.570
Willingness-to-pay for WaterGuard (KSh, BDM)	11.8	12.1	12.0	11.6	12.4	12.0	0.943
Principal component of asset variables	0.06	-0.02	0.07	-0.04	-0.04	0.00	0.611
Sample size (for household-level tests)	240	480	440	482	440	2122	
Water source-level variables:							
Total households at water source	48.8	45.9	44.0	43.3	50.6	46.3	0.544
Active source committee prior to project	0.33	0.35	0.55	0.42	0.44	0.42	0.692
Water source is improved	0.75	0.74	0.82	0.63	0.78	0.74	0.676
Sample size (for water source-level tests)	12	24	22	24	22	104	

Notes : Tests for equality of means of houseohld-level variables conducted using means clustered at the water source level.

Table 2: Fundraising at up-front payment treatment dispensers

	Number of contributors	Proportion of users who contributed	Mean contribution	Total funds raised
Mean	51.9	1.3	50.6	1399
Median	51	1.15	25.9	1260
Standard Deviation	28.4	0.642	141	656
Observations	48	46	48	48

Notes: Data are from contribution logs kept by dispenser fundraising committees (up-front payment treatment groups only). The two communities that failed to raise the required minimum are included as having raised zero contributions.

Table 3: Water user perceptions of removal threat, knowledge of fundraising committee

	(1)	(2)	(3)	(4)
	Dispenser will be removed if the community does not pay for the chlorine refills		Correctly names member of fundraising committee	
Up-front payment	-0.122***	-0.122***	0.059	0.069*
	(0.037)	(0.039)	(0.036)	(0.037)
Threat of Removal	0.249***	0.243***	0.008	-0.007
	(0.038)	(0.038)	(0.035)	(0.034)
Free Provision	-0.280***	-0.277***		
	(0.044)	(0.044)		
Baseline controls included?	no	yes	no	yes
Observations	1,858	1,858	1,781	1,781
R-squared	0.153	0.156	0.013	0.026
Number of clusters	102	102	89	89
Mean in comparison group	0.286	0.286	0.303	0.303

Notes : Baseline controls are those shown in Table 1; missing values for explanatory variables replaced with sample means. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Dispenser knowledge and chlorine use at follow-up survey

	(1)	(2)	(3)	(4)	(5)	(6)
	Gives correct instructions for dispenser use		Chlorine found in dispenser		Household water tests positive for chorine	
Up-front Payment	-0.039	-0.021	-0.066	-0.066	-0.025	-0.022
	(0.027)	(0.026)	(0.110)	(0.118)	(0.023)	(0.023)
Threat of Removal	-0.036	-0.031	0.193*	0.163	-0.003	-0.003
	(0.028)	(0.025)	(0.109)	(0.114)	(0.023)	(0.024)
Free Provision	-0.042	-0.031	0.197	0.184	0.000	0.001
	(0.035)	(0.035)	(0.165)	(0.176)	(0.037)	(0.037)
Baseline controls included?	no	yes	no	yes	no	yes
Observations	2,023	2,023	104	104	1,743	1,743
R-squared	0.022	0.033	0.116	0.200	0.017	0.025
Number of clusters	102	102			104	104
Mean in comparison group	0.797	0.797	0.455	0.455	0.249	0.249

Notes : Baseline controls are those shown in Table 1; water source averages are used for water-source level outcomes. Missing values for explanatory variables replaced with sample means. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Chlorine observed in tank at unannounced spot checks

	(1)	(2)	(3)	(4)	(5)
Model	Linear probability with random effects		Linear probability		
Time since installation	5, 8, and 11 months (pooled)	5, 8, and 11 months (pooled)	5 months	8 months	11 months
Outcome	Chlorine in tank	Chlorine in tank	Chlorine in tank	Chlorine in tank	Chlorine in tank
Up-front Payment	-0.064	-0.056	0.065	-0.041	-0.214**
	(0.057)	(0.061)	(0.098)	(0.104)	(0.095)
Threat of Removal	0.199***	0.186***	0.166*	0.172*	0.259***
	(0.057)	(0.058)	(0.097)	(0.103)	(0.094)
Free Provision	0.467***	0.457***	0.336**	0.420**	0.644***
	(0.093)	(0.094)	(0.159)	(0.170)	(0.155)
Baseline controls included?	no	yes	no	no	no
Observations	312	312	104	104	104
R-squared	0.162	0.211	0.214	0.170	0.300
Mean in comparison group	0.424	0.424	0.409	0.455	0.409

Notes : Baseline controls are water source averages of variables shown in Table 1. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Number of 3 mL doses purchased per household over 11 months

	(1)	(2)
	Doses per household	Doses per household
Up-front payment	0.791	2.629
	(7.502)	(8.048)
Threat of Removal	18.82**	19.33**
	(7.533)	(8.491)
Free Provision	159.0***	158.9***
	(24.06)	(24.69)
Baseline controls included?	no	yes
Observations	104	104
R-squared	0.636	0.644
Mean in comparison group	40.11	40.11

Notes : Baseline controls are water source averages of variables shown in Table 1.
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1