Micro-ordeals, targeting, and habit formation[1]

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September 12, 2013

Preliminary and Incomplete

Abstract

When health goods are provided free, some households may take the goods but not use them in ways that promote health. User fees may screen out those who will not use the goods for health purposes, but may also exclude some who would use the good for health purposes. We show that in the case of dilute chlorine solution for water treatment, a micro-ordeal requiring households to redeem monthly coupons to obtain a free supply targets the product to those who will use the chlorine solution for water treatment. Over a range of realistic parameter values a principal who values health will prefer either free delivery of chlorine solution or free provision with a coupon micro-ordeal to a 50% subsidy. The micro-ordeal also seems to increase take up of water treatment after subsidies end, likely because it helps households build a habit of procuring the chlorine solution.

[1] We thank IPA Kenya for its collaboration, Ken Gatobu, Bastien Michel, Sean Sylvia, Nicolas Studer, and Stephanie Ruiz for research assistance, as well as Moses Baraza and his team for outstanding data collection. This study was funded by the Bill & Melinda Gates Foundation and Dartmouth College.
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1. Introduction

In many contexts, a principal would like an agent to undertake an action which cannot be directly observed. One tool at the disposal of the principal is to provide the agent an input which is complementary to the desired action. For example, a principal might fund tuition to promote tertiary education, mosquito nets to encourage malaria prevention, or chlorine solution to promote water treatment. In the context of preventive health, free provision of inputs such as deworming medication, mosquito nets, and water treatment solution has been shown to substantially increase health the use of these products (Kremer and Miguel, 2007; Dupas, 2009 and 2012; Hoffmann, 2009; Cohen and Dupas, 2010; Kremer et al., 2011b; Tarozzi et al., 2013).

However, if inputs are delivered for free or at low cost, some agents may accept the complementary input but not undertake the desired action. Students may accept scholarships but spend their time drinking rather than attending class or studying; households may accept a mosquito net or chlorine solution but not use these in ways that promote the principal's health goals. Thus Ashraf et al. (2010) argue that households which are willing to obtain water treatment solution at a low price but not at a high price are more likely to use the solution for non-health purposes (household cleaning). Cohen et al. (2013) find that charging more for anti-malaria medication disproportionately reduces the chance that those who do not actually have malaria take the medication. In such cases, the principal faces a tradeoff between type I errors or errors of inclusion (people receive a health product but do not use it in ways that promote health), and type II errors or errors of exclusion (people who would use the product do not receive it).

In other cases, however, charging for health inputs does not seem to target those individuals who would likely experience the largest health benefit from use of the input. In rural Kenya, Miguel and Kremer (2007) show that parents of children suffering from intestinal worms are no more likely to purchase deworming medication than those whose children are not infected. Ashraf et al. (2010) find that mothers of young children in urban Zambia do not exhibit a higher valuation for water treatment solution than others who are offered the product. In the case of mosquito nets, Cohen and Dupas (2010) and Dupas (2012) show that, in rural Kenya, those randomly given the chance to get a free or very cheap mosquito net are no less likely to use it for malaria prevention than those who self-select into purchasing the net at a higher price. Tarozzi et al. (2013) find that households in the Indian state of Orissa receiving nets free of charge are even more likely to use them than those who self-select into purchasing, and Hoffmann (2009) shows that in rural Uganda, the most vulnerable household members are more likely to use mosquito nets when these are received free of charge.

We examine the impact of imposing a very small non-monetary cost, which we term a "micro-ordeal", on the use of a health product, both before and after a period of subsidy. Ordeal mechanisms, under which individuals are required to expend effort in order to qualify for a benefit, are sometimes used to target transfers to the poor (Nichols and Zeckhauser, 1982; Parsons, 1991; Alatas et al., 2012). The larger the benefits allocated through an ordeal mechanism, the greater the ordeal that will be necessary to exclude the ineligible. In some cases, this could create substantial deadweight losses. For example, the National Rural Employment Guarantee Act (NREGA) in India transfers resources to the poor by requiring recipients to work on public projects, many of which are believed to have little useful value. We examine whether ordeal mechanisms may be used for a different purpose: targeting health inputs to those most likely to use them for health purposes. If the non-health value of a health product is small, it may be possible to screen out those who do not intend to use the product for health purposes with only a “micro-ordeal” that does not impose high welfare costs on those who intend to use the product for health purposes. Micro-ordeals may be useful targeting devices if willingness to use a product for health purposes is correlated with willingness to undergo the associated ordeal. Due to cash constraints and the opportunity cost of time, willingness to undergo an ordeal may be a better predictor of willingness to use a product for health purposes than willingness to pay a monetary cost.

Structuring a micro-ordeal in a way that rehearses behaviors associated with procuring and using the product may additionally impact behavior through habit formation. Preventive health behavior requires potentially scarce attention (Banerjee and Mullainathan, 2008), both to undertake the health behavior itself, and also in many cases to remember to procure necessary inputs, for example water treatment solution or prescription drugs. The attention cost of a particular behavior may be reduced through repetition of the behavior, leading to the establishment of a habit (Verplanken and Wood, 2006). Indeed, there is evidence that other preventive health behaviors (exercise, for example), are subject to habit formation (Charness and Gneezy. 2009; Gneezy, Meier, Rey-Biel 2011; Royer et al. 2011). Note that there may also be other ways that temporary subsidies could affect long-run use of a product, for example by allowing consumers to learn about the user experience or effectiveness of a good (Kremer and Miguel, 2007; Dupas, 2012) or through price anchoring (Koszegi and Rabin, 2006). If habit formation is important, then structuring a micro-ordeal in a way that requires households to rehearse the behavior(s) involved in continued procurement and use of a product could potentially increase long-term use, after free provision has ended, in ways that go beyond the learning and price-anchoring channels.

We examine the case of dilute chlorine solution, which can kill many of the organisms causing diarrhea. Diarrhea is a major killer of children and also imposes smaller health costs on other age groups. The currently dominant approach to distribution of water treatment solution is social marketing and sales to households through retail shops, at a cost of approximately $0.31 US per one month supply.[3] This typically generates take up of no more than 10 percent (Kremer et al., 2011b). An alternative or supplementary approach (similar to that evaluated by Loharikar et al., 2012) would be free provision of the product to households with young children, who would experience the greatest health benefit. Some households, however, would likely not use the solution for water treatment, even if it were provided free of charge, for example, due to an aversion to the taste of chlorine. We consider the problem of a principal who is concerned with health but who also places some value on the cost to households of imposing an ordeal, and who faces a shadow value of using funds to promote health in other ways. We identify conditions on the principal's valuation of health and on the cost to households of the micro-ordeal under which the principal would (1) fully subsidize and freely deliver a health good, (2) impose a micro-ordeal for the fully subsidized good, (3) subsidize 50% of the current price, or (4) continue the current social marketing policy. (We cannot empirically test the full range of potential approaches the principal could potentially use.)

Our study followed over 1,500 parents coming to rural health centers in western Kenya. Some had the opportunity to purchase water treatment solution at a 50% discount; some were given free bottles of the solution; and some were given coupons which could be redeemed for the

[3] This price is designed to cover the cost of goods sold, but not the social marketing which is funded by donors.

product at a local shop over the course of a year. We compare water treatment across arms both in the short run, while households were using the solution received through the study, and two years after the distribution, by which time the free or subsidized chlorine had been exhausted.

Our empirical estimates suggest that compared to free distribution of water treatment solution to mothers of young children, the micro-ordeal of requiring mothers to redeem a coupon for the solution free of charge at a nearby store can avoid most of the type I error of providing the solution to those who will not use it for water treatment, at the cost of only a small (and statistically insignificant) increase in type II error of reduced use by those who would have otherwise used chlorine for water treatment. This implies that the alternative of a micro-ordeal greatly expands the range of the parameter space over which the principal would prefer free distribution of water treatment solution to the current social marketing approach, even when supplemented with a 50% discount.

Moreover, we find that the micro-ordeal seems to have a dynamic benefit of establishing habits of water treatment solution purchase and use. In particular, purchase and use of the product remain elevated among those who received coupons a year after the end of the subsidy, whereas those directly given either a small or large sample of the treatment solution were no more likely to purchase or continue using it. We interpret this finding as suggesting that subsidizing free experimentation with the product and thus learning, is not enough – establishing a habit of product procurement appears necessary to increase market demand in the long run. Based on these results, we argue that micro-ordeals that involve replicating the steps necessary to obtain a product in the absence of the subsidy may encourage longer-run use once subsidies are removed. Suitably-designed micro-ordeal mechanisms thus appear to have the potential to be appealing for at least two reasons: they can not only improve targeting of subsidies in the short-run, they can also generate longer-lasting adoption.

The remainder of the paper proceeds as follows. Section 2 provides background on the study setting and intervention. Section 3 sets up the problem facing a principal who values use of the product for child health, potentially more than some agents. Section 4 describes the study design and data. Section 5 presents results on the impact of imposing a micro-ordeal on take up of water treatment solution and on use of water treatment. In Section 6 we calibrate the model based on these results to examine how the preferred solution for the principal depends on the weight placed on health benefits and on the welfare cost imposed by the ordeal. Section 7 presents evidence on the lasting impacts of the various policies on water treatment after the subsidy has ended. Section 8 discusses what models of behavior might fit the empirical facts and concludes.

2. Background

Diarrhea is the second leading cause, after pneumonia, of child mortality globally (Fisher Walker et al., 2013), and the leading cause of mortality among children aged five years and younger in Kenya (Black et al., 2010). Over 70 percent of child deaths due to diarrhea occur between the ages of six months and two years (Fisher Walker et al., 2013). While young children carry the heaviest mortality burden, others whose immune systems are compromised are also vulnerable to diarrheal disease. Particular pathogens, such as those that cause cholera and typhoid, pose significant risks to otherwise healthy individuals across age groups.

Water is a major channel for the transmission of diarrheal disease, and a number of randomized controlled trials have investigated the impact of point of use water treatment on child diarrhea. Arnold and Colford (2007) review this literature and, averaging across 21 studies, find that point of use chlorination reduces reported child diarrhea by an average of 29% overall. Rates of verified chlorine use in the six trials among these for which such information is available vary from 40 to 100%, with an average use rate of 74%. (achieved through frequent visits and reminders to subjects). The intent-to-treat estimate of 29% thus corresponds to a treatment-on-the-treated estimate of 39%.

In Kenya, the non-governmental organization PSI/Kenya began marketing small bottles of dilute chlorine solution branded as 'WaterGuard' in May 2003. At the onset of this study in fall 2007, 150ml bottles of WaterGuard were commonly sold at retail shops, at the price of 20 Kenyan Shillings (Ksh), around US$ 031. Take-up of water chlorination in the study setting of rural Western Kenya was low, however. Kremer et al. (2011b) report that only 7% of rural households in that part of Kenya were using chlorine to treat their drinking water as of 2008.

The study took place in Kenya's Western Province, which has the highest prevalence of child diarrhea in Kenya (CBS and ORC Macro, 2003), and is relatively poor, with an average agricultural wage of approximately $US 0.16 per hour (Duflo et al., 2011). Research participants were recruited from the waiting rooms of rural maternal and child health clinics in Busia District. Offering subsidies for water treatment solution through maternal and child health clinics offers the opportunity to reach a large proportion of the population vulnerable to diarrheal disease. Health clinics in Kenya already offer a wide range of free or subsidized products to pregnant women and mothers of young children (including free bed nets and free antimalarial drugs).

Because treating water with chlorine affects its taste, achieving high usage rates is challenging, even when chlorine solution is offered free of charge. Previous work in diverse contexts shows that the rate of verified water treatment is around 50% or less when treatment solution is provided free but encouragement is less intensive than in typical efficacy trials (see for example Kremer et al, 2011b, Luoto et al. 2011 and Luoto et al. 2013). Another challenge in delivery of this product for point of use water treatment is that it degrades over time (Lantagne et al., 2011). Chlorine's rate of decay accelerates rapidly once a bottle is opened.

Degradation of chlorine after water has been treated also presents challenges for the observation of household water treatment. Residual chlorine may no longer be detectable in stored treated water after as few as 24 hours (Null and Lantagne, 2013). Since households in the study setting typically collect drinking water every one to three days, the result of a test for residual chlorine represents a lower bound of actual usage.

3. Principal's Problem

We examine the problem of a principal who primarily values child health, but also puts some weight on non-health consumption of the poor. This might be a reasonable approximation of the objective function of certain international donors or officials in some ministries of health. We take these preferences as given and address the question of what policy would be preferred by such a principal over a range of possible weights on health and non-health utility, rather than trying to solve the problem of a social planner trying to maximize welfare among households. We therefore do not make claims about social optimality or what a social planner would do.

That said, there are many potential reasons why a social planner might also want to put greater weight on use of the product for health purposes than would the decision makers within the household. Externalities from communicable diseases are one example. The social planner might put higher weight on child health expenditures relative to adult expenditures than the parents. Contracting between parents and children is likely imperfect. Households may not understand the health impact of chlorine treatment and this information may be expensive to credibly convey. Behavioral factors such as time inconsistency might also limit take up.

Consider a principal who derives benefit z_i from household i's use of a health product, h_i, to promote health, and also values the household's non-health utility $u_{,i}$. Future benefits achieved through the continued use of the product due to learning or habit formation ("continuation value") are also valued by the principal. Letting S denote the total cost of subsidies to promote use of the health good, the principal's payoff is:

$$\sum_i (z_i \cdot h_i + u_i + continuation\ value_i) - S. \qquad (1)$$

Because some households may accept a subsidized health good but not use it for a health purpose, we distinguish between "takers" and "users", where the former includes all of those who take the good, regardless of whether and how they use it, and the latter refers to those who use the health good for the health purpose. From the perspective of a principal considering whether to increase spending on subsidies or other measures to increase access to the health product from some baseline level, increasing spending is preferred if the value of health benefits generated by marginal users of the product, plus any changes in the non-health utility of marginal and inframarginal users, exceed the opportunity cost of the spending increase:

$$(z + du_{mar} + continuation\ value) \cdot use_{mar} + du_{inf} \cdot use_{inf} \qquad (2)$$

$$> \left(ds \cdot take_{inf} + s \cdot take_{mar}\right).$$

On the left-hand side of this inequality is the per-household benefit (suppressing subscript i) of a potential policy change to the principal. The health benefit of the policy change is the individual value of this benefit, z, multiplied by use_{mar}, the proportion of households induced to use the product under the new policy, and the non-health utility benefit to such households is represented by du_{mar}. The effects of continued use by marginal users after the end of the subsidy may include impacts on both health and non-health utility. Households that already use the health product for the health purpose experience no additional health benefit, but may experience an increase in non-health utility du_{inf} through the reduced monetary or effort cost of obtaining the product. The proportion of such households is represented by use_{inf}. On the right-hand side is the principal's cost of the potential policy change: ds is the change in the cost of the policy per household that takes the health product, while s is the new cost per taker. The terms $take_{inf}$ and $take_{mar}$ represent the proportion of households already taking the health product before the change and those newly induced to take it, regardless of whether they use it for the health purpose.

In the field experiment described below, we consider three policy options, each representing a change to the status quo of no subsidy for water treatment solution: 50% subsidy with delivery, full subsidy with micro-ordeal, and full subsidy with delivery. While we test for the existence of a continuation value beyond the subsidy period, our comparison of policies from the principal's perspective is based on take up and usage of water treatment solution while the subsidy is in place.

Before concluding this section, we note that for the principal, all that matters in evaluating a particular policy from a static point of view is the expenditure required by the principal under that policy, the number of people actually using the health product under the policy, and the total non-health costs to households under the policy. If the principal values health benefits to the household even after children are older than five, then they would care about the impact of the policy on longer-run chlorine use for water treatment. These are the four sufficient statistics for the principal, independent of the underlying model of household behavior. While thinking about the underlying behavioral model is interesting, this is not the primary goal of this paper – but we discuss which types of model would be consistent with our results in Section 8.

4. Study Design

4.1. Experimental Treatment Groups

All study participants were offered either partially or fully subsidized water treatment solution, and provided with detailed information about the dangers of drinking contaminated water and thorough instructions on how to use the solution to purify their drinking water. Participants were randomized across the following treatment groups.

***50% DISCOUNT treatment*:** Water treatment solution was made available for immediate purchase at a 50% discount off the retail price. Participants could to purchase up to 5, 150 mL bottles of the solution (enough to last 5 to 7 months), at 10 Kenyan Shillings (Ksh) per bottle (around 0.125 USD).

***MICRO-ORDEAL treatment*:** Twelve coupons, each redeemable for one 150 mL bottle of water treatment solution at a local shop were provided. Each coupon was marked for a specific month, for the next 12 consecutive months, and participants were given a calendar to track the expiration of coupons.

***FREE DELIVERY treatment*:** Two 500 ml bottles were provided, one immediately and the second given during a follow-up home survey, 3-5 months later.[4] At the time they received the

[4] The supply was given in the form of two separate bottles due to concerns about chlorine degrading over time (see Lantagne et al., 2011).

first bottle, participants were informed they would receive a second bottle later. This supply of 1,000 ml of water treatment solution was expected to last 7 to 9 months.

***FREE SAMPLE treatment*:** One 150 mL bottle was given as free sample. This was expected to last between one month and six weeks (upon opening) for a typical household purifying all its drinking water.

In each of the *50% DISCOUNT*, *MICRO-ORDEAL*, and *FREE DELIVERY* treatments, participants were offered the opportunity to obtain sufficient water treatment solution to last them to the first follow-up survey. Comparing take up and usage at first follow-up (after 3 to 5 months) across these groups thus allows us to identify the targeting effects of varying the price and effort cost of obtaining the product.

The amount of water treatment solution offered through the *FREE SAMPLE* treatment was much lower, and likely not sufficient to last until the first home follow-up visit. This treatment allowed people to learn about the user experience of treating water (e.g., the taste of chlorine in purified water), and allows us to examine whether this type of learning affects long-run demand.

Note that we do not have a pure control group. This ensures that the endorsement of the water treatment solution by the research team is constant across each of the treatment arms. When estimating the impacts on adoption after the subsidy ended, we benchmark all full-subsidy treatments (*FREE SAMPLE, FREE DELIVERY,* and *MICRO-ORDEAL*) against the *50% DISCOUNT* group, under which take up was lowest. To the extent that the *50% DISCOUNT* treatment increased usage after the end of the subsidy, we will be underestimating the dynamic effects of the full subsidy treatments, but this will have no bearing on our ability to compare impacts across the main potential policies of interest (full subsidy with micro-ordeal vs. full subsidy with delivery).

4.2. Sampling and Randomized Assignment Procedures

A total of 1,560 parents of children aged six to twelve months, an age group at high risk for mortality due to diarrheal disease, were recruited from the waiting rooms of four rural maternal and child health clinics, located in four separate market towns, during the period from November 2007 through June 2008, by a team of trained enumerators.[5]

Once enrolled, study participants were administered a baseline survey. The survey collected information on basic demographics, current water treatment practices, knowledge about waterborne illness and diarrhea prevention, and child health. At the end of the survey, respondents were randomly assigned to an experimental arm by choosing an envelope from a bag full of identical envelopes. Each envelope contained a letter corresponding to one of four experimental arms. Once the respondent selected an envelope and revealed the letter, the enumerator offered the corresponding treatment.

4.3. Sample characteristics and balance check

Table 1 describes characteristics of the sample at baseline. Given our sampling frame, our sample is composed of two categories of health center visitors: those with a sick child who needed care, and those who brought their child for a routine visit such as well-baby check-ups or vaccinations. Those two categories appear almost equally sized in our sample.

[5] A disruption in enrollment occurred from late December 2007 through early March 2008, due to widespread violence following Kenya's presidential election on December 27, 2007. We therefore consider those enrolled prior to the crisis as "wave 1" (502 participants) and those enrolled after the crisis as "wave 2" (1,058 participants).

Almost all of the respondents are the mother of the child who was brought to the clinic, and the average age is 24 years. The mean educational attainment is completion of primary school (8 years of schooling).[6] Respondents lived approximately 4 km from the clinic on average,[7] and about 70 percent walked to the clinic that day. Shops where the coupons given to the *MICRO-ORDEAL* group could be redeemed, which were located within a few hundred feet of the clinic where recruitment occurred, were in the nearest market center for 20% of respondents. Reports of drinking water treatment and boiling are likely subject to very large social desirability bias, with earlier work in the area reporting no difference in *E coli* levels between households which report and do not report boiling water (Kremer et al., 2011a). However, for what it's worth, only 29% of respondents report that they had used chlorine to treat their water in the past six months, and 21% reporting boiling in the past week.

Table 1 also presents tests of balance across the four experimental groups. Characteristics appear generally balanced across treatments, with the exception that those in the *FREE SAMPLE* and *MICRO-ORDEAL* groups are approximately one year older than those in the comparison group. The fact that two of the 72 comparisons are significant at the five percent level is well within what we would expect given a successful randomization. There are also slight differences across treatments in the proportion of respondents for whom the clinic visit was prompted by illness versus routine care, whether the respondent walked to the clinic, and whether the shop where coupons could be redeemed is in the market center nearest to the respondent's home, but none of these are significant at the 5% level. In the analysis below, we systematically show

[6] Educational attainment among our sample of clinic attendees is three years higher, on average, than among the sample, drawn from randomly selected rural households, in a study on chlorine adoption by Kremer et al. (2011b) conducted in the same area at around the same time.

[7] Directions to respondents' place of residence were collected at baseline, and GPS coordinates were obtained at the first follow-up visit. The distance to clinic based on these coordinates are summarized here.

specifications both without and with controls for the variables in Table 1, and find no differences across them.

4.4. Follow-up Data

We use three types of follow-up data in our analysis.

Coupon Redemption Monitoring. The research team partnered with four local shops where the coupons distributed to respondents in the *MICRO-ORDEAL* arm could be redeemed. Shops were monitored to ensure stock-outs would not prevent coupon redemption, and shopkeepers were trained to collect voucher stubs and to record the unique ID assigned to each voucher along with redemption date. This information was collected every two weeks by the research team.

First follow-up survey (3-5 months): Three to five months after enrollment, enumerators visited study participants in their homes to assess whether the water treatment solution, if obtained, was in use, and conducted a survey on household water treatment practices and perceptions of child health. Enumerators used colorimeters to test for the presence of residual free chlorine in the household water supply.[8] Chlorine decays over time after it is added to water, and may reach undetectable levels after 24 hours. Since most people store their water for 2-3 days after treating it, we would expect some treated water to test negative for residual chlorine. We can therefore think of observed residual chlorine in the water as a lower bound on actual usage (Null and Lantagne, 2012).

For those enrolled in wave 1 (prior to the election crisis), the timing of the follow-up was delayed due to the post-election violence. The average gap between baseline and first follow-up

[8] As per the CDC, "the presence of residual chlorine in drinking water indicates that: 1) a sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrheal disease; and, 2) the water is protected from recontamination during storage. The presence of free chlorine in drinking water is correlated with the absence of most disease-causing organisms, and thus is a measure of the potability of water." Protocols used for water testing were identical to those described in the appendix of Kremer et al. 2011a.

for those in wave 1 is 139 days (4.5 months), whereas the average gap for those in wave 2 is 109 days (3.6 months).

Second follow-up survey (2 years): Two years after completion of the intervention (April-September 2010), 1,340 respondents (all those in the *50% DISCOUNT*, *FREE DELIVERY* and *MICRO-ORDEAL* groups, and a random half of those in the *FREE SAMPLE* group) were selected for inclusion in a second follow-up survey, using the same survey instrument and again testing the household water supply. In addition, in order to test for the effect of early-life exposure on preferences for the taste of water, a taste test was administered to children who were aged between 6 and 12 months at the time of enrollment in the study. Children were given sips of clean, un-chlorinated water and clean, chlorinated water and asked to choose from which cup they would like to drink more water. Adults were also asked about their preference for the taste of un-chlorinated versus chlorinated water. The stickiness of tastes past childhood has been identified as having a role in the inelasticity of health behavior in other contexts. In particular, Atkin (2012) argues that taste formation in childhood leads to a low elasticity of food choices to relative prices in India.

5. Results

5.1. Take-up

Table 2 presents regression analysis of the take-up of the various treatments offered. The top row shows the mean of the dependent variable. The first two columns focus on take-up in the *50% DISCOUNT* arm. Take-up in this arm was modest. About half of the participants in this group elected to purchase at least one bottle (column 1) and only 11% purchased more than one.[9] Overall, only 13.4% of the 5 bottles offered per respondent were purchased (column 2). The coefficient estimates on the covariates show that take-up was slightly higher among older respondents, and among those with more years of education. Fewer bottles were purchased by those who were visiting the clinic for an illness rather than routine care, which is not surprising since we would expect those respondents to be less likely to engage in preventive health behavior. Finally, those who walked to the clinic were 19 percentage points (36.6%) less likely to purchase any discounted chlorine solution. Since we control for distance to the clinic, walking (rather than taking public transportation) can be seen as an indicator of poverty, suggesting that poorer individuals are less likely to purchase water treatment solution for which a positive price is charged, compared to those who are wealthier.

We consider the *FREE SAMPLE* and *FREE DELIVERY* arms in the next four columns. In those arms, take-up at the time of enrollment was 100% (no one rejected the free bottle they were given). We can look at what people reported doing with the bottle in the follow-up survey to get an upper bound on their own use. We examine two outcomes in these two groups: whether the respondent reports keeping the free bottle received at the clinic for personal use, and whether they report giving it away to a friend or neighbor (we assume that those who did neither of these things threw the bottle away, as only a few report the bottle was stolen). The vast majority of people report keeping the bottle for personal use: 91% in the *FREE SAMPLE* group and 86% in the *FREE DELIVERY* group. Similar to the *DISCOUNT* group, take-up among those in the *FREE DELIVERY* group is increasing in age and in the level of education.

[9] For reference, Cohen and Dupas (2010) finds that 93% of pregnant women elected to buy an antimalarial bed net at the price of 10Ksh (the price of the chlorine bottle after the 50% discount).

The last three columns present analysis using redemption data from the *MICRO-ORDEAL* arm. The vast majority of participants, 85%, redeemed at least one coupon (column 5),, and 39.8% of all coupons distributed, a mean of 4.8 of the 12 given to each participant, were redeemed (column 6), in contrast to only 13.4% of total chlorine purchased in the *50% DISCOUNT* group . The proportion of participants who redeemed coupons in the month prior to the first follow-up interview three to five months after the baseline is approximately equal to the overall coupon redemption rate, at 41% (column 7).

Similar to the other treatments, we see an age gradient in coupon redemption, but unlike other treatments, years of education is not a significant predictor of take up. Those who had walked to the clinic (likely to be poorer, conditional on distance to clinic) redeemed 8.7 percentage points more of the total coupons received (approximately one additional coupon) on average than those who took public transport, suggesting that the ordeal mechanism, in contrast to the price mechanism, resulted in higher take-up among the poorest compared to the less poor. This effect could be due to a lower opportunity cost of time among the poorest. Coupon redemption was lower for those who report boiling their drinking water. This finding is consistent with the hypothesis that those who do not plan to use the treatment solution – because they prefer to purify their water by boiling or because they judge this to be a socially acceptable excuse to decline to treat their water – are screened out by the inconvenience of redeeming coupons. Inconvenience appears to be a significant deterrent to redemption: those who lived further from the clinic redeemed fewer coupons on average – though this effect is significant only at the 10 percent level. We validate the relationship between wealth level and take-up using data on assets collected during the short-run follow-up survey. Asset ownership is positively correlated with purchase of the treatment solution, and there is some evidence of a negative correlation with coupon redemption.[11]

5.2. Results: Water Purification Behavior During the Program Period

Table 3 presents results on the effects of the interventions on water purification behavior during the five months for which sufficient water treatment solution was offered to participants assigned to the *50% DISCOUNT*, *MICRO-ORDEAL*, and *FREE DELIVERY* treatments. The proportion of participants in each treatment group with a positive chlorine test, conditional on stratification variables (clinic and wave dummies) are reported in the first row. The second row shows results which are conditional on baseline variables from Table 1. The results conditional on baseline controls are very similar to those without. We focus our discussion and analysis on the latter specification, for which estimated adoption under the micro-ordeal is lower relative to free delivery. This implies that the benefit of the micro-ordeal policy relative to free delivery, as derived in the following section, is more conservative than it would be using the unconditional means.

The proportion of households with a positive chlorine test was 12.4% in the *50% DISCOUNT* group. This level is significantly below the proportion of those in each of the full subsidy groups with positive test results. Rates of positive residual chlorine tests in the *FREE DELIVERY* and *MICRO-ORDEAL* groups are almost identical. This result suggests that the inconvenience of redeeming a coupon screened out very few of those who would have used chlorine if given it directly. The proportion of households with water testing positive for residual

[11] Those is with a higher wealth index are less likely to redeem at least two coupons ($p<0.1$), but the relationship between the asset index and the overall proportion of coupons redeemed is not statistically significant. Results available upon request

chlorine in the *MICRO-ORDEAL* group was 33 percent, while that in the *FREE DELIVERY* group was only 1.2 percentage points higher, at 34.2%.[12]

In the *FREE SAMPLE* group, the share of households with confirmed chlorine use was 20.5%. Given that the free sample was expected to last between one month and six weeks for an average-size family, and the follow-up took place on average 3.9 months after it was distributed, this suggests that households used chlorine intermittently. This could be because households wanted to save the chlorine solution for a time when the returns are highest, for example during a cholera outbreak, or because they sometimes remembered to purify and sometimes didn't.[13]

While we do not vary the cost of the micro-ordeal experimentally, we can use variation in whether the shop at which coupons could be redeemed was located in the market center nearest to a participant's home. As shown in Table 4, participants who could redeem coupons at the nearest market center were 12.6 percentage points more likely to have redeemed a coupon in the month prior to the first follow-up interview than those who had to go further out of their way to redeem coupons, unconditional on other covariates. This difference is significant at the 10% level.[14] Despite being more likely to take the water treatment solution, households who could redeem coupons at the nearest market were only 4 percentage points more likely to be using the

[12] We can rule out that this effect is driven by households in the *FREE DELIVERY* group running out of chlorine: rates of chlorination among households in the *MICRO-ORDEAL* and *FREE DELIVERY* treatments who were surveyed within three months of the intervention are likewise practically identical, with the unadjusted and adjusted means differing by 1.4 percent and 1.1 percent respectively, and the first 500mL received were definitely more than enough to carry a household through at least three months.

[13] In rural western Kenya, the seasonal prevalence of child diarrhea is highest December to February and lowest September to November (Audi et al., 2013). The rate of chlorination over the survey period does not follow this seasonal pattern. However, outbreaks of particular waterborne diseases such as cholera can occur at any time of year. During outbreaks, the government often runs public information campaigns publicizing the health threat and encouraging households to chlorinate their drinking water. A cholera outbreak occurred in Kenya December 2007 to May 2008, and a public health alert was issued on April 10, 2008. Reports of cholera cases continued through at least June 25. Among wave 1 households, for whom the short-run follow-up was conducted in spring of 2008, we observe a spike in chlorine use immediately after the April alert.

[14] As shown in Table 2, this relationship is greater in magnitude and more statistically significant when controlling for other covariates.

solution to treat their water, according to chlorine test results. This finding suggests that the size of the micro-ordeal matters: smaller ordeals may generate higher take up, but may be less effective at screening out those who do not use a good for its intended purpose.

6. Payoff to Principal from Different Policies

Using the short-run results, we can estimate the benefit, from the perspective of the principal, of moving from the status quo of charging 20 Kenyan shillings for a 150 mL bottle of water treatment solution, to progressively stronger steps to induce use. To do this, we calibrate the model presented in Section 3, using our reading of the medical literature on the impact of chlorine on health. Note however that the model could as easily be calibrated with alternative estimates of the health impacts. Our goal is not to make normative judgments about the desirability of any particular policy, but rather to discuss how the principal's payoff can be computed and compared across the potential policies considered.

A common metric used by health policy makers to compare the benefits of alternative interventions is the number of disability-adjusted life years (DALY) saved at a given cost. In this analysis, we use the number of DALYs saved through averted child deaths as the outcome valued by the principal, and examine which policies are preferred as the principal's value per DALY saved varies.

The under-five mortality rate in Kenya at the time of the study was 82.5 per 1000 live births, 20.5% of which (16.9 per 1000) were due to diarrheal disease (Black et al., 2010). We multiply diarrhea-specific child mortality by 0.39, based on Arnold and Colford's estimate of a 29% (intent to treat) reduction in the risk of diarrhea, adjusted for an average compliance rate of 0.74. This calculation implies that consistently treating water with chlorine reduces the probability that a child dies in the first five years of life by 0.66%. We then multiply this reduction in mortality risk by 2.92, the average number of children below the age of five years per household in our sample, for a per-household reduction in the probability of a child death of 1.94% over five years, or 0.39% per year. The average age of a child death due to diarrhea is 1.6 years.[15] Using the standard assumption that healthy life expectancy at birth is 81.25 years, and applying a 3% discount rate to future years of life as is standard practice for computing DALY values (Prüss-Üstün et al., 2003), an averted child death is equivalent to 30.28 DALYs.[16]

Substituting z_{DALY}, the principal's valuation of a DALY saved for the more general health benefit term z_i into equation 2 in Section 3, moving to a policy of lower barriers to use is preferred by the principal if the following inequality is satisfied:

$$\sum(z_{DALY} + du_{mar}) \cdot use_{mar} + du_{inf} \cdot use_{inf} > (ds \cdot take_{inf} + s \cdot take_{mar}). \quad (3)$$

Any utility gains through use of the product among those induced to use it for drinking water treatment, use_{mar}, are through its impact on health, and thus subsumed in the principal's value of health benefits, z_{DALY}. Changes in the effort cost of acquisition, however, are not included in z_{DALY}, and so must be included separately as dU_{mar} when calculating the benefit of a given policy change. The utility value of a policy change to inframarginal users is equal to the value of any reduction in the price of chlorine, plus the utility value of any savings in the effort cost of acquisition. We assume that any change in utility to households that obtain the good but do not use it for the health purpose is not valued by the principal.

[15] Calculated from data presented in Figure 2, Fischer Walker et al., 2013.
[16] Discounting future years of life is somewhat controversial (see for example Anand and Hanson, 1997). Not discounting future years of life implies almost 79.6 DALYs saved per child death averted, which would imply that for a given

Table 5 shows the values of each of the parameters in equation 3 for a series of policy changes, each representing a reduction in the barriers to acquiring chlorine, and the conditions under which each of these policy changes is preferred by the principal. The first comparison is between the status quo policy of no subsidy and the effort cost of procurement, and a 50% subsidy coupled with delivery to households (zero effort cost). At the time of the study, chlorine solution was sold at a price of 20 Kenyan shillings (approximately 0.31 USD) per 150 mL bottle, for a one-month supply. Since the experimental design did not include a pure control group, we do not have experimental results on chlorine take up or water treatment under this policy. However, we are able to use data from the baseline survey to estimate that 7.1% of households treated their water treatment at the unsubsidized price $\left(use_{inf} = 0.071\right)$.[18] We can then use results from the *50% DISCOUNT* treatment to estimate the proportion of households that would take up water treatment if such a partial subsidy were introduced. Overall, 13.4% of the 5-month supply of chlorine offered to households in this group was purchased, and almost all of these households used chlorine to treat their water: at the 3-5 month interview, the water of 12.4% of households in this treatment tested positive for residual chlorine, 5.3% more than at baseline $(use_{mar} = 0.053)$. Assuming that all of those who paid the unsubsidized price for chlorine used it to treat their water, we estimate that marginal takers $(take_{mar})$ constituted 6.3% of households. For the 7.1% of inframarginal users in this comparison, we count the cash value of the subsidy, $1.85 US over the course of a year, plus the saved effort of monthly procurement, $12 \cdot \varepsilon$ as direct benefits to non-health utility. For those induced to use chlorine by the partial

[18] We only have self-reported data on use at baseline (since the baseline took place at the health centers where respondents were recruited, not at home). To obtain an estimate of verified use, we multiply the proportion who report using by the ratio of verified to self-reported usage at the long-term follow-up (0.68). To the extent that reporting bias is influenced by the intervention, we expect this effect to be diminished two years later. This value is similar to the baseline chlorination rate of 7.3% reported by Kremer et al. (2011b) for the same region of Kenya during the same year.

subsidy, the utility benefit is through health, and so not included in the private non-health benefit.

Considering next a move from a policy of partial subsidy with delivery to one of full subsidy with a coupon micro-ordeal, we use the proportion of households treating their water in the *MICRO-ORDEAL* group to estimate that the additional users generated through this shift would constitute 20.6% of households $(use_{marg} = 0.206)$. Using the proportion of coupons redeemed overall (39.8%) as our measure of take-up –%, we estimate the proportion of marginal takers in this comparison as 0.264.[20]

Inframarginal users in this comparison gain a monetary value of $1.85 from the increased subsidy level. In addition, both inframarginal and marginal users incur the effort cost of redeeming coupons, which we assume is equal to the cost of purchasing chlorine, reducing utility by , $12 \cdot \varepsilon$ over 12 months.

Finally, going from a 100% subsidy with micro-ordeal to 100% subsidy with free delivery increases the rate of water treatment by 1.2 percentage points, and the number of takers by 0.602.[21] Moving to the free delivery policy, inframarginal users are saved the effort cost of coupon redemption.

For all of the policies considered, we assume that the cost of the program is simply the cost of subsidized chlorine. Clearly there are other costs, for example the cost of administering a

[20] The proportion of households in the *MICRO-ORDEAL* group who redeemed their coupon for the month prior to the follow-up survey was 41.4%. Using this as the measure of takers instead of the overall coupon redemption rate has no substantive impact on the results.

[21] We include in our definition of takers those who reported giving away the water treatment solution they received. It is not clear whether this chlorine was actually given away or simply not used (and giving away was seen as a socially acceptable reason for lack of use). If it was given away, we do not observe whether it was used by the recipient for water treatment. Excluding those who report giving chlorine away from the analysis does not substantively alter our conclusions

coupons system, and transportation and staff costs of delivery – which we abstract from here. Such costs are likely to vary widely across contexts, but based on the actual costs of implementing the policies in this study, we expect that free delivery is by far the most costly approach, since this involves transporting chlorine directly to households.

We can compute conditions relating the cost of the ordeal, ε to the dollar value per DALY, z_{DALY}, under which each policy is preferred to one with incrementally higher barriers to use. These conditions are shown in the last column of Table 5. Mapping these conditions over z_{DALY} and ε space reveals the combinations of these two variables under which each of the policies considered is preferred. We consider first the principal's decision among the status quo of zero subsidy, introducing a 50% subsidy, and a 100% subsidy with delivery. Figure 1 illustrates the regions over which each of these policies is preferred. Even at the modest value of $19 / DALY, the 50% subsidy is preferred to no subsidy. When the value placed on a DALY reaches $126 – well below the $241 per DALY saved threshold recommended by the World Bank (World Bank, 1993)[22], the 100% subsidy with free delivery becomes more attractive than the 50% subsidy.

Introducing the possibility of the micro-ordeal policy in Figure 2 greatly increases the parameter space over which a 100% subsidy is preferred by the principal. Using this policy is optimal when the principal's value per DALY is as low as $41, assuming the ordeal imposes no welfare cost. As the cost of the ordeal of coupon redemption increases, imposing this ordeal becomes less attractive, until eventually free delivery is preferred. At the $241 / DALY cost effectiveness threshold, the cost of the ordeal at which free delivery becomes preferable is 0$.48, well over the current price of chlorine solution, and 3 hours valued at the unskilled hourly wage

[22] This reflects the $150 benchmark, converted to 2013 dollars using the US CPI . Taking into account real income growth would increase the threshold still further.

in this area.[23] The fact that the ordeal mechanism reduced water treatment by only 1.2% suggests its welfare cost is likely much lower than this .

7. Long-Run Impacts on Water Purification Behavior

7.1. Results

As summarized in the figure below, the features of the four experimental arms considered in the study enable us to estimate the relative importance of three possible channels through which temporary subsidies affect long-run adoption: enabling recipients to try water treatment over a short period and learn about the user experience; enabling recipients to try it for a much longer period, possibly enabling learning about health impacts and hence net benefits; and creating a habit of procurement. Specifically, given that only about half of participants in the 50% DISCOUNT group obtained any water treatment solution through the study, comparing the long-run effects of the *FREE SAMPLE* treatment to that in the *50% DISCOUNT* group provides an estimate of the importance of learning about the user experience. Comparing the long-run effects of the *FREE DELIVERY* treatment to that of the *FREE SAMPLE* sheds light on the additional effect of observing the health returns to water treatment. Finally, comparing the *MICRO-ORDEAL* treatment to the *FREE DELIVERY* treatment allows us to identify the additional effect of having to regularly visit the local store to procure the subsidized bottles. We call this *procurement habit formation*: those required to redeem coupons may become so accustomed to obtaining chlorine from the shop on a regular basis that the behavior becomes almost automated, requiring little cognitive effort.

[23] Duflo et al. (2011) use an hourly wage rate of $0.16 for this region.

Mechanisms through which long-run adoption could be affected

Panel A. Features of Experimental Treatments

	Endorsement	Subsidy Level	Quantity subsidized	Delivery
50% DISCOUNT	Yes	50%	Small	Direct
FREE SAMPLE	Yes	100%	Small	Direct
FREE DELIVERY	Yes	100%	Large	Direct
MICRO-ORDEAL	Yes	100%	Large	Coupon

Panel B. Mechanisms through which Long-run Adoption Could be Affected

	Endorsement	Learning about user experience	Time for potential learning about health benefits (months)[±]	Procurement habit formation
50% DISCOUNT	Yes		0.67	
FREE SAMPLE	Yes	Yes	1	
FREE DELIVERY	Yes	Yes	6.67	
MICRO-ORDEAL	Yes	Yes	4.8	Yes

[±] Average months' supply of chlorine obtained, according to manufacturer-recommended use.

Table 6 presents results on the long-run effects of the experimental treatments. The coefficients on *FREE SAMPLE*, *FREE DELIVERY*, and *MIRCO-ORDEAL* show the effects of assignment to each of these groups relative to the *50% DISCOUNT* group. The average outcome for the *50% DISCOUNT* group is presented in the bottom row, and p values of F tests comparing each of the treatment effects against one another are shown below. In addition to verified chlorine usage, we consider a second outcome: the total amount spent on water purification products in the past 6 months (self-reported). We find relatively large effects of the *MICRO-*

ORDEAL treatment. While only 19.3% of households in the *50% DISCOUNT* had detectable chlorine in their water, this went up to 27.6% in the *MICRO-ORDEAL* group, corresponding to a 43% increase. This difference is significant at the 5% level. And while households in the *50% DISCOUNT* group spent only 20 Kenyan shillings on average on water treatment products in the previous 6 months, the amount spent in the *MICRO-ORDEAL* group is 30 Kenyan shillings, corresponding to a 50% increase, also significant at the 5% level. In contrast, neither receiving a small amount of chlorine in the *FREE SAMPLE* treatment, nor a 7-month supply in the *FREE DELIVERY* treatment affected reported or verified use, nor did these treatments impact expenditures on chlorine. Taken together, these results suggest that neither learning about the user experience nor the potential for learning about net benefits from chlorinating water were enough to spur long-run adoption. The procurement habit that the *MICRO-ORDEAL* treatment helped form was a necessary condition.

7.2. Mechanisms

For habit formation to explain the long-run effect of the *MICRO-ORDEAL* treatment on water treatment, a necessary condition is that those observed treating their water at the long-run follow-up are indeed those households who regularly redeemed coupons. We check whether this holds in the data in columns 1-6 of Table 7. We find that indeed redemption behavior is positively correlated with long-run water treatment. Of course this positive correlation, while a necessary condition for habit formation to be a plausible explanation for the long-run patterns, is by no means sufficient to *prove* that the mechanism is habit formation. Indeed the correlation could be due to omitted variable bias (the same people who care about chlorine redeem coupons more and use chlorine more, both before and after the treatment).

So far we have assumed the only difference between the *MICRO-ORDEAL* and *FREE DELIVERY* treatments is in the procurement habit formation that the coupons enabled, and the finding that the *MICRO-ORDEAL* treatment had a large impact on long-run adoption while the *FREE DELIVERY* treatment did not, suggests an important role for such habit formation. We now discuss a few potential alternative explanations for this difference and rule them out.

Taste formation? While both provided enough water treatment solution to potentially enable learning about health returns, the amount provided through the *MICRO-ORDEAL* treatment was more than the *BIG BOTTLE* treatment: the quantity received under the latter was fixed at 1,000 mL, therefore households that redeemed seven coupons or more (30% of those in the *MICRO-ORDEAL* treatment) received more of the treatment solution. To the extent that longer exposure to chlorinated water decreases distaste for it, part of the *MICRO-ORDEAL* effect could develop would requirethrough taste formation. To test for this, columns 7 and 8 of Table 7 consider the long-term effects of subsidies for the treatment solution on preferences. Adult respondents were asked whether they prefer the taste of chlorinated or non-chlorinated water. Overall, just under half of respondents reported a preference for chlorinated water. We do not see a differential effect of the *MICRO-ORDEAL* treatment on this preference, suggesting that taste formation is not the mechanism driving long-term adoption of water treatment.[24]

Learning about Procurement? Second, if people were unaware of how to obtain water treatment solution prior to the intervention, redeeming coupons at a shop that normally carries this product could allow them to *learn about procurement*. To test for this, columns 11 and 12 of Table 7 show the results of a regression of positive chlorine test on treatment dummies, and interactions of each treatment with whether the respondent had purchased chlorine in the six months prior to

[24] The choices of young children between chlorinated versus non-chlorinated water were likewise unaffected by any of the treatments (results available from the authors).

the baseline interview. If the long term effect of the *MICRO-ORDEAL* treatment arose through learning about procurement, we would expect the treatment effect for this group to be concentrated among those who had not previously purchased. We do not see evidence of this; the point estimates of each of the treatments interacted with previous purchase are all positive and statistically insignificant.

Stockpiling? Finally, one could be worried that, at time of the long-run follow-up (2 years after baseline and a year after the last valid coupon), those in the *MICRO-ORDEAL* group were still using water treatment solution received through the study. According to the manufacturer of WaterGuard, the product's shelf life is 9 to 12 months from date of manufacture if unopened. Once opened, the solution should be used within two months, because exposure to air causes it to lose potency (PSI and UNICEF, p. 13). This suggests that it is possible, though unlikely, that chlorine received through the study was still potent enough to be detectable at the long-run follow-up visit. To test for this possibility, we compare the proportion of those in each group who reported using chlorine they had received for free, the last time they treated their drinking water. Results are shown in columns 9 and 10 of Table 7. Freely distributed chlorine accounts for a sizeable share of that used by this sample: 18.5 percent of respondents in the *50% DISCOUNT* group report that the last time they purified their water, they used chlorine received free of charge. This proportion is significantly higher among those in the *FREE DELIVERY* treatment. Recalling that verified chlorine usage was not higher in this group at the long-term follow-up than among those in the benchmark 50% *DISCOUNT* treatment, we conclude that, on average, the chlorine received through the study lasted the longest for those in the *FREE DELIVERY* group, but that even these participants had used up their chlorine by the time of the long-term follow-up survey.[25] The proportion reporting that the chlorine most recently used had been obtained for free was identical in the *FREE SAMPLE* and *MICRO-ORDEAL* groups, with neither group significantly different on this dimension from those in the 50% *DISCOUNT* treatment.

7.3. Attrition

This section discusses potential concerns with attrition in the follow-up surveys (attrition is not a concern for the voucher redemption data). Table A1 presents regression analysis of how attrition varied by experimental arm in both the short-run follow-up (columns 1-2) and the long-run follow-up (columns 3-6). We consider attrition as it affects the main outcome variables of interest: in the short-run this is whether water test data is missing; in the long run follow-up we also consider whether the reported expenditure on chlorine over the past six months is missing. The first two columns suggest that attrition in the first follow-up survey was relatively modest (given that we had to trace the home location of respondents sampled through clinics), and not differential. Attrition was 10.3% in the *50% DISCOUNT* group, and not significantly higher or lower in the other groups. This suggests that selection bias is unlikely to be an issue when comparing outcomes across groups in the short-run.

In contrast, as shown in columns 3 to 6, attrition in the second follow-up survey was relatively high, at 39.9% for the chlorine test result and 36.2% for the water treatment expenditure variable in the *50% DISCOUNT* group. Attrition is also somewhat differential across groups, with fewer attriters in all three full-subsidy groups (*FREE SAMPLE, FREE DELIVERY,* and *MICRO-ORDEAL)* than in the *50% DISCOUNT* group, though the difference is significant only for the self-reported expenditure data in the case of the *FREE DELIVERY* treatment, and only at the 10 percent level. Attrition is balanced across each of the full subsidy groups, with the

[25] The mean number of coupons redeemed by the *MICRO-ORDEAL* households was 4.8. This translates to 720 mL of chlorine solution, less than the 1000 mL distributed through the *FREE DELIVERY* group.

rate for *FREE DELIVERY* and *MICRO-ORDEAL* almost identical. While we focus attention on those treatment arms for which attrition is balanced, its high level overall implies that we must make some assumptions about the behavior of attriters.

In the results presented above, we implicitly assumed that attriters used chlorine at the same rate as those in their respective experimental group who were successfully surveyed. In Table A2, we present results using alternative assumptions. The estimates in column 1 are the most conservative we consider: they assume that attriters use at the same rate as those observed in the treatment group considered. For example, in the estimated effect for the *FREE SAMPLE* group, all attriters (including those in the *50% DISCOUNT* group) are assumed to use at the rate observed among those in the *FREE SAMPLE* treatment. Column 3 shows the treatment effect assuming attriters in all treatment groups used at the same rate as those in the *50% DISCOUNT* group who were observed at the long-term follow-up. This is the least conservative assumption. Finally, we make the intermediate assumption that attriters' rate of usage is the mean of that observed in the *50% DISCOUNT* group and in the treatment group for which the effect is estimated; these results are reported in column 2. Estimates controlling for baseline observables are reported in columns 4 through 6.

All of these alternative assumptions attenuate the estimated treatment effects. This is due to assuming identical behavior among a third of the sample, irrespective of the treatment to which an individual was assigned. Despite this, under all but the most conservative assumption, the coupons treatment still has an effect on chlorine adoption that is significant at the 10 percent level.

8. Discussion

So far we have focused on the principal's problem, which can be solved with the sufficient statistics discussed in Section 3 and estimated in Section 6, irrespective of the underlying household behavior. But since understanding the underlying behavioral channels may be important for generalizing to other contexts, and because understanding household behavior may be of independent interest, this section discusses the classes of model that could or could not fit our results in both the short and long run.

The simplest household model one could consider would be one in which all households have some non-health use of chlorine with value x but the benefits of using chlorine for water treatment vary across households due to differences in the utility associated with chlorine's taste. In this model, charging a price of just above x screens out those households with negative valuations of chlorine for health purposes who would not use chlorine for health purposes even if it were provided to them for free, as well as those households with health valuations between 0 and x. Thus in this model, charging a small amount x with free delivery, or imposing a coupon system requiring households to exert some effort to acquire the product, would be very similar from the standpoint of the principal.

The principal's choice between these alternatives would depend on how the cost of delivering chlorine to customers compared with the cost of having customers come pick it up with a coupon. In practice, delivery costs are likely to be larger, since chlorine only lasts for a limited time before degrading and hence a delivery model would require regular trips to the household.

While the model sketched above is parsimonious, it misses some features of the context and the data. If households vary in their wage, and if this affects the relative price of time and money for households, then a monetary price and a coupon redemption ordeal that yield the same overall levels of demand for the health product will generate a different composition of households who obtain it. In particular, charging for the product will tend to generate a wealthier set of customers than requiring customers to spent time picking it up. Depending on the correlation between wages and willingness to use the product, either a pricing system or an ordeal system might lead to greater use of the health product for the health purpose, and thus might be more attractive to the principal for any fixed values of the delivery cost parameters discussed above. Indeed, as discussed in Section 5.1, relatively well-off households in our study were more likely to purchase water treatment solution, while redemption of coupons for chlorine appeared to be inversely correlated with wealth status. This suggests that in order to fit the data, a model of individual behavior should allow for heterogeneity among households in the cost of the ordeal (in money units); for heterogeneity in willingness to use the health product for the health purpose once it has been obtained; and for the possibility of positive or negative correlation between these two types of heterogeneity.

Neither the parsimonious model of homogeneous households, nor the richer model that allows for potentially correlated heterogeneity in the relative cost of the ordeal and of taste for the health good, would suggest that the choice of a particular mechanism would influence use of the health good at some future time (once access to the subsidized product had ended). In Section 7.1, however, we presented long-run evidence suggesting a habit formation channel in procurement behavior.

One possibility is that people have limited attention and that some don't even think about the possibility of water treatment. It seems reasonable to believe that those people who do not even think about the possibility of water treatment will also not think about possibility of going to the shop to procure treatment solution. In this case, targeting those who are willing to procure WaterGuard will also effectively target those who will use the product for water treatment. One interpretation of our evidence on the contemporaneous effect of the micro-ordeal is thus that there is a strong correlation between paying attention to the possibility of procuring Waterguard and paying attention to the possibility of using it for water treatment. This makes the micro-ordeal of having to redeem a coupon an effective screening mechanism from the standpoint of a principal concerned about health.

In order to explain the dynamic path of coupon redemption and the apparent impact of micro-ordeals after the WaterGuard subsidy is withdrawn, however, a model would need to include a few more features. First, there must be some separate attention required for picking up the treatment solution at a store that is distinct from the attention necessary to remember to use the product once one has it in the house. Second, the act of redeeming the coupon must reinforce a habit of procurement, thus reducing the attention required for this task. Moreover, it's likely that matching the data would require a model in which attention to the possibility of using WaterGuard varies across people, but is not an immutable characteristic. One could imagine random shocks to attention that either increase the attention people pay to water treatment or displace that attention to other issues. For example, a household worried about a domestic crisis or a bad harvest might cease to devote attention to water treatment. On the other hand, a cholera epidemic or an intervention from a nurse or a survey enumerator might increase the attention paid to water treatment. This type of model might help explain why coupon redemption rates start out relatively high and fall over time. The initial clinic interaction may increase attention to water treatment, but this may fall off over time due to random shocks that demand attention.

Note that this model suggests that interaction with someone promoting water treatment may serve as a shock to attention. In this case a survey in which an enumerator visited households, and offered to sell WaterGuard would lead people to be more likely to purchase the product than they would otherwise, but without any guarantee that they will use it once the marketer has left, if the non-health conscious state quickly returns. If this is the case, it would have some interesting methodological implications for studies estimating demand curves experimentally through door-to-door marketers offering products on the spot at randomly varying prices, rather than randomly varying discount vouchers that households then need to take to a local shop. The heightened demand from the marketer may be particularly acute for products which are fairly cheap (e.g. a one month bottle of chlorine solution, as opposed to a mosquito net or a cook stove.) Note that to the extent that this bias exists, it may lead to much higher rates of non-use of a product than would be encountered in situations more typical to those that would be generated in the context of a large-scale program.[26]

A micro-ordeal mechanism – requiring people to redeem coupons – can effectively target a health input to those who will use it. In the western Kenyan setting where the study took place, this requirement led to levels of chlorine use statistically indistinguishable from those observed when people were given chlorine directly. Apparently, anyone who valued treated water enough to chlorinate their water also valued it sufficiently highly to redeem a coupon. This is striking, because only between a third and half of those given chlorine for free used it to treat their water

[26] The costs of door-to-door delivery are so great that it seems extremely unlikely that a program to subsidize chlorine solution, for example, would be implemented in this way. We believe that the coupon program we examine would be a plausible way to scale up free distribution to the most vulnerable age group.

on a regular basis. Introducing the effort of coupon redemption as a cost of obtaining free chlorine eliminates waste by targeting the subsidized chlorine to those who are more likely to use it, without reducing take-up among intended beneficiaires -- those who are unable to pay the unsubsidized price but willing to use the free product for health purposes.

Of course, the extent to which micro-ordeals are preferred depends on the products considered. In particular, it will depend on the potential utility gains from alternative, non-health uses of the product. For example, in the same area of Kenya, Cohen et al. (2013) find that everyone is willing to pay the effort cost of visiting a local drug shop to redeem a voucher for highly subsidized antimalarials, including those with a very low probability of having malaria. This means a larger micro-ordeal would be needed for effectively discouraging those with a low malaria risk to take the antimalarial. What's more, for products that are highly valued for their health use, imposing a micro-ordeal may be inefficient. For example, Dupas (2012) finds that 97.5% of households who received a voucher for a free antimalarial bed net went to their local store to redeem it.[27] This suggests that that giving people bed nets directly would not have substantially changed targeting, and would have saved people the effort cost of acquisition.

Micro-ordeals like coupons are also attractive as a means of targeting particular populations with subsidies. In this case, subsidies were targeting parents of young children by using health clinics as a catchment. This targeting can be replicated at a larger scale, as the NGO PATH and the CDC have explored in Malawi, and as done by the Tanzania National Voucher Scheme (a discount voucher for an insecticide-treated net given to pregnant women and parents of young children through health centers). Coupons or vouchers could easily be bundled in safe birthing kits, which are an increasingly common intervention.

[27] Appropriate usage of bed nets a year later was extremely high, at 88%.

Our results also suggest that, for a health product requiring high-frequency restocking, putting people through the ordeal that they would have to go through absent a subsidy (i.e., procuring the product at the local store) may be necessary for the subsidy to generate long-run effects on adoption. We find that households required to go to this effort were more likely to be using chlorine a full year after the last coupon could be redeemed. We conjecture that it is because repeated behavior of redeeming coupons established a habit of acquiring chlorine from a shop where it could normally be purchased. The finding that a temporary subsidy can lead to long-term adoption echoes Dupas' (2012) result that receiving a coupon for a free ITN leads to higher willingness to pay one year later, but the finding that *how* the subsidy is delivered matters (i.e., home delivery versus coupons) suggests caution in extrapolating these results. While learning through experience may lead to long-run adoption of some products and behaviors, this effect may be limited in the presence of high-frequency transaction costs (such as having to replenish one's stock of chlorine on a monthly basis), and in such cases, habit formation appears to be an important and necessary mechanism through which new behaviors can be established and maintained.

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Table 1. Summary Statistics and Balance Check

	Experimental Arm:				Randomization Checks					
	50% DISCOUNT (CONTROL)	*FREE SAMPLE*	*BIG BOTTLES*	*MICRO-ORDEAL*	P-val (FREE = C)	P-val (BIG = C)	P-val (MICRO-ORDEAL = C)	P-val (BIG = FREE SAMPLE)	P-val (MICRO-ORDEAL = BIG BOTTLES)	P-val (FREE SAMPLE = BIG BOTTLES)
	Mean *Std. Dev.*	Mean *Std. Dev.*	Mean *Std. Dev.*	Mean *Std. Dev.*						
Characteristics of Respondent										
Female	0.99	0.99	0.99	1.00	0.764	0.746	0.299	0.517	0.165	0.428
Age (in years)	23.38	24.36	23.99	24.41	0.014	0.141	0.016	0.341	0.334	0.959
	(5.41)	(5.81)	(5.10)	(5.73)						
Years of Education	8.58	8.55	8.57	8.57	0.921	0.966	0.942	0.954	0.906	0.858
	(2.66)	(3.01)	(2.80)	(2.61)						
Characteristics of Clinic Visit during which Respondent was sampled										
Visit prompted by illness (not routine care)	0.45	0.45	0.51	0.48	0.826	0.090	0.31	0.116	0.489	0.984
Distance from home to clinic (km)	3.92	4.01	4.00	3.77	0.822	0.813	0.461	0.986	0.320	0.396
	(2.89)	(3.77)	(3.24)	(3.99)						
Walked to clinic	0.68	0.66	0.65	0.71	0.406	0.410	0.445	0.985	0.105	0.314
Baseline Health Behavior										
Gave birth at health facility (last birth)	0.36	0.36	0.38	0.35	0.935	0.691	0.727	0.613	0.445	0.099
Child slept under a bednet previous night	0.82	0.82	0.86	0.83	0.968	0.159	0.498	0.148	0.458	0.776
Boiled drinking water last week	0.20	0.21	0.21	0.21	0.761	0.955	0.788	0.801	0.827	0.500
Used Chlorine in past 6 months	0.30	0.29	0.29	0.31	0.939	0.870	0.540	0.925	0.427	0.980
Bought Chlorine in past 6 months	0.24	0.24	0.26	0.27	0.984	0.493	0.321	0.481	0.751	0.468
Observations (Total=1560)	352	441	385	382						

Table 2. Take-Up by Treatment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	50% DISCOUNT			*FREE SAMPLE*		*BIG BOTTLES*		*MICRO-ORDEAL*		
	Purchased at least one bottle at clinic	Purchased at least two bottles at clinic	# of bottles purchased (0 if none) at clinic	Reports keeping sample for own use	Reports giving away sample	Reports keeping first big bottle for own use	Reports giving away first big bottle	Redeemed at least one coupon at shop	Redeemed at least two coupons at shop	# of coupons redeemed (0 if none) at shop
Age of respondent (in years)	0.000	0.009***	0.014*	0.007**	-0.004*	0.007*	-0.007*	0.005	0.012***	0.142***
	(0.005)	(0.003)	(0.008)	(0.003)	(0.002)	(0.004)	(0.004)	(0.003)	(0.004)	(0.036)
Years of Education	0.015	0.011	0.039**	-0.003	-0.006	0.027***	-0.022***	0.009	0.018*	0.118
	(0.011)	(0.007)	(0.018)	(0.006)	(0.004)	(0.008)	(0.008)	(0.008)	(0.010)	(0.085)
Visit prompted by illness (not routine care)	-0.036	-0.099***	-0.172*	-0.033	-0.020	0.009	-0.037	-0.002	-0.005	-0.546
	(0.056)	(0.036)	(0.089)	(0.030)	(0.023)	(0.042)	(0.039)	(0.038)	(0.047)	(0.404)
Distance from home to clinic	-0.002	-0.006	0.000	0.002	-0.001	-0.002	0.005	-0.007	-0.011	-0.103*
	(0.011)	(0.007)	(0.018)	(0.004)	(0.003)	(0.007)	(0.006)	(0.005)	(0.007)	(0.058)
Walked to Clinic	-0.193***	-0.110***	-0.311***	0.064*	-0.025	-0.013	0.007	0.043	0.140**	1.073**
	(0.063)	(0.041)	(0.101)	(0.033)	(0.025)	(0.048)	(0.045)	(0.043)	(0.054)	(0.462)
Gave birth at health facility (last birth)	-0.021	-0.024	-0.061	-0.013	0.007	-0.038	0.012	-0.003	-0.044	-0.359
	(0.059)	(0.038)	(0.094)	(0.033)	(0.024)	(0.045)	(0.042)	(0.040)	(0.050)	(0.424)
Child slept under a bednet previous night	0.060	0.053	0.109	0.021	0.015	-0.065	0.079	-0.004	0.003	0.448
	(0.074)	(0.048)	(0.118)	(0.041)	(0.031)	(0.061)	(0.057)	(0.050)	(0.062)	(0.529)
Boiled drinking water last week	-0.032	0.017	-0.056	0.034	-0.027	-0.022	0.009	-0.109**	-0.038	-0.664
	(0.068)	(0.044)	(0.109)	(0.036)	(0.027)	(0.051)	(0.048)	(0.045)	(0.056)	(0.476)
Used Chlorine in past 6 months	-0.234**	-0.009	-0.220	-0.071	0.067	0.012	0.024	-0.012	-0.117	-0.636
	(0.118)	(0.076)	(0.189)	(0.066)	(0.049)	(0.119)	(0.113)	(0.092)	(0.116)	(0.986)
Bought Chlorine in 6 months preceding BL	0.196	-0.029	0.183	0.073	-0.090*	0.041	-0.060	0.026	0.130	0.939
	(0.127)	(0.082)	(0.204)	(0.070)	(0.053)	(0.124)	(0.117)	(0.096)	(0.121)	(1.030)
Observations	352	352	352	362	362	318	318	382	382	382
R-Squared	0.089	0.092	0.089	0.088	0.051	0.069	0.064	0.074	0.104	0.117
Mean of Dep. Var.	0.517	0.119	0.668	0.914	0.044	0.855	0.126	0.853	0.715	4.775

Notes: Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3. Positive chlorine test at household visit 3-5 months after intervention

TREATMENT:	*50% DISCOUNT*	*MICRO-ORDEAL*	*FREE DELIVERY*	*FREE SAMPLE*
Means and standard errors adjusted for:				
Stratification	0.124	0.337	0.344	0.213
	(0.019)	(0.039)	(0.039)	(0.038)
+ Baseline controls	0.124	0.330	0.342	0.205
	(0.019)	(0.039)	(0.039)	(0.038)

Notes: Standard errors in parentheses.

Table 4. Take up and usage by distance to redemption point

	Number of households	Redeemed coupon month of survey	Positive chlorine test
Redeemable at nearest market	72	0.514	0.377
		(0.503)	(0.488)
Not redeemable at nearest market	275	0.388	0.337
		(0.488)	(0.474)

Notes: Standard errors in parentheses. Data is from participants in *MICRO-ORDEAL* treatment who were observed at first follow-up interview (data on location of home is not available for attriters).

Table 5: Conditions under which each policy is preferred by the principal

	use_{inf}	$use_{\,mar}$	du_{inf}	du_{mar}	$take_{inf}$	$take_{mar}$	S	dS	Policy of lower barriers to use is preferred if: $\sum(z_{DALY_i} + du_{mar,i}) \cdot use_{mar} + du_{inf,i} \cdot use_{inf} > (ds \cdot take_{inf} + S \cdot take_{mar})$
current price to 50% subsidy with delivery	0.071	0.053	$\$1.85 + 12 \cdot \varepsilon$	0	0.071	0.063	\$1.85	\$1.85	$z_{DALY} > \$18.68 - 137\ \varepsilon$
50% subsidy with delivery to 100% subsidy with coupons	0.124	0.206	$\$1.85 - 12 \cdot \varepsilon$	$-12 \cdot \varepsilon$	0.134	0.264	\$3.69	\$1.85	$z_{DALY} > \$41.03 + 164 \cdot \varepsilon$
100% subsidy with coupons to 100% subsidy with delivery	0.330	0.012	$12 \cdot \varepsilon$	0	0.398	0.602	\$3.69	0	$z_{DALY} > \$1576.96 - 2809 \cdot \varepsilon$
50% subsidy with delivery to 100% with delivery	0.124	0.218	\$1.85	0	0.134	0.866	\$3.69	\$1.85	$z_{DALY} > \$125.58$

Table 6. Long-Term Effects: Chlorine Usage at 2nd Follow-up (after 2 years)

	(1)	(2)	(3)	(4)	(5)	(6)
	Reports that Drinking Water Container was treated with purification product last time it was filled		Water Sample Tests Positive for Chlorine[a]		Total spent on purification products in past 3 months (Ksh)	
Time since baseline						
FREE SAMPLE	0.051	0.049	0.031	0.020	0.880	1.500
	(0.051)	(0.050)	(0.046)	(0.045)	(5.585)	(5.606)
BIG BOTTLES	-0.028	-0.020	0.019	0.024	-4.706	-3.804
	(0.044)	(0.043)	(0.039)	(0.038)	(4.780)	(4.806)
MICRO-ORDEAL	0.069	0.062	0.083**	0.079**	10.32**	10.14**
	(0.044)	(0.043)	(0.039)	(0.039)	(4.822)	(4.835)
Baseline Controls?	No	Yes	No	Yes	No	Yes
Observations	924	924	850	850	910	910
Mean in *50% DISCOUNT* group	0.383	0.383	0.193	0.193	20.43	20.43

*Notes: Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include clinic dummies, wave dummies, and the number of days between baseline and follow-up. Baseline controls included in columns 2, 4 and 6 are all those presented in Table 2.*

[a] For some households, water container was empty and coulnd't be tested.

Table 7. Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)
Mechanism:	Taste Formation?		Stockpiling?		Learning how to purchase?	
Data Source:	Short-Run Follow-up		Long-Run Follow-up			
	Adult reports preferring chlorinated taste in water		Reports that chlorine most recently used to treat water was received for free		Water Sample Tests Positive for Chlorine[a]	
FREE SAMPLE	0.002	0.008	0.112*	0.110*	0.014	0.006
	(0.051)	(0.052)	(0.0580)	(0.0581)	(0.052)	(0.051)
BIG BOTTLES	0.004	0.009	0.178***	0.175***	0.010	0.012
	(0.044)	(0.044)	(0.0510)	(0.0512)	(0.045)	(0.045)
MICRO-ORDEAL	0.030	0.031	0.00190	0.00411	0.073	0.079*
	(0.045)	(0.045)	(0.0508)	(0.0509)	(0.045)	(0.045)
Bought pre BL					0.057	-0.123
					(0.066)	(0.118)
FREE SAMPLE X bought pre BL					0.089	0.065
					(0.108)	(0.108)
BIG BOTTLES X bought pre BL					0.030	0.052
					(0.088)	(0.088)
MICRO-ORDEAL X bought pre BL					0.034	0.002
					(0.089)	(0.089)
Baseline Controls?	No	Yes	No	Yes	No	Yes
Observations	920	920	673	673	850	850
Mean in *50% DISCOUNT* group	0.473		20.43		0.193	

	(7)	(8)	(9)	(10)	(11)	(12)
Mechanism:	Habit Formation?					
Data Source:	Long-Run Follow-up					
	Total spent on purification products in past 3 months (Ksh)		Water Sample Tests Positive for Chlorine at Long-Run Follow-up			
Total number of coupons redeemed	2.688**	2.610*	0.025***	0.022***		
	(1.353)	(1.437)	(0.007)	(0.007)		
Number of months between baseline and last coupon redeemed					0.023***	0.019***
					(0.006)	(0.007)
Baseline Controls?	No	Yes	No	Yes	No	Yes
Observations	266	266	246	246	246	246

*Notes: Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include clinic dummies, wave dummies, and the number of days between baseline and follow-up. Columns 1-2 include a control variable indicating whether chlorinated or non-chlorinated water was tasted first. Baseline controls included in even-numbered columns are all those presented in Table 2. Columns 7-12: sample restricted to MICRO-ORDEAL group.*

Table A1. Attrition at Follow-up

	(1)	(2)	(3)	(4)	(5)	(6)
	Short-Run Follow-up (3-5 months)		Long-Run Follow-up (2 years)[a]			
	Chlorine test result is missing		Chlorine test result is missing		Reported expenditure on water treatment is missing	
FREE SAMPLE	-0.022	-0.024	-0.029	-0.016	-0.037	-0.024
	(0.021)	(0.021)	(0.041)	(0.039)	(0.040)	(0.038)
BIG BOTTLES	0.010	0.012	-0.053	-0.047	-0.060*	-0.051
	(0.018)	(0.018)	(0.036)	(0.034)	(0.034)	(0.032)
MICRO-ORDEAL	-0.017	-0.008	-0.040	-0.033	-0.056	-0.047
	(0.018)	(0.019)	(0.036)	(0.034)	(0.035)	(0.032)
Baseline Controls?	No	Yes	No	Yes	No	Yes
Observations	1,560	1,560	1,340	1,340	1,340	1,340
Mean in *50% DISCOUNT* group	0.103	0.103	0.399	0.399	0.362	0.362

*Notes: Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.*

[a] *100% of respondents in the DISCOUNT, MICRO-ORDEAL and BIG BOTTLES groups, and 50% of those in the FREE SAMPLE group, were sampled for the long-run follow-up.*

Table A2. Long-Term Effects with high and low bound assumptions about attriters

	(1)	(2)	(3)	(4)	(5)	(6)
	Water Sample Tests Positive for Chlorine					
	lower bound	mean estimate	upper bound	lower bound	mean estimate	upper bound
FREE SAMPLE	0.020	0.020	0.021	0.019	0.019	0.020
se	(0.566)	(0.586)	(0.607)	(0.549)	(0.563)	(0.577)
BIG BOTTLES	0.011	0.011	0.012	0.011	0.012	0.013
se	(0.030)	(0.030)	(0.029)	(0.030)	(0.029)	(0.029)
MICRO-ORDEAL	0.051	0.053*	0.055*	0.059*	0.060*	0.062**
se	(0.032)	(0.031)	(0.031)	(0.032)	(0.031)	(0.031)
Baseline Controls?		No			Yes	
Observations		1340			1340	

Notes: Consumers who pu lower bound: attriters use at the same rate as treatment group
mean estimate: attriters use at mean rate of treatment and control
upper bound: attriters use at the same rate as control group

Figure 1. Principal's preferred policy given $ value / DALY and cost of purchase (no micro-ordeal option)

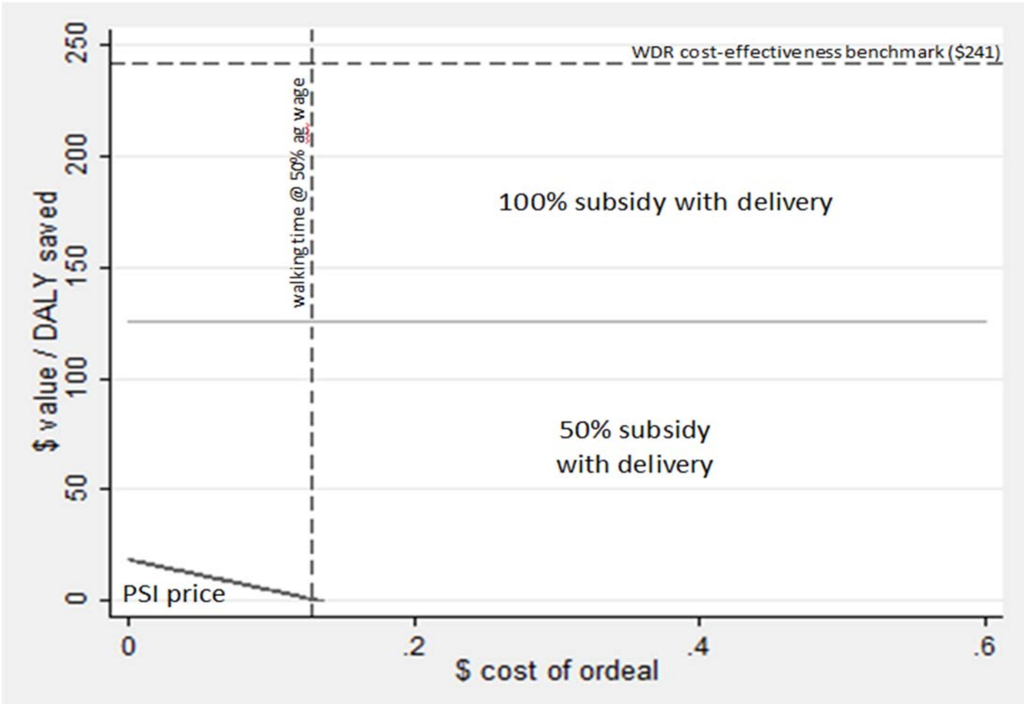

Figure 2. Principal's preferred policy given $ value / DALY and cost of purchase including micro-ordeal option