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Working With Community Health Workers to Increase Use of ORS and Zinc to Treat Child Diarrhea In Uganda: A Cluster Randomized Controlled Trial

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Working With Community Health Workers to Increase Use of ORS and Zinc to Treat Child Diarrhea In Uganda: A Cluster Randomized Controlled Trial

by
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A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy
in
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of the
University of California, Berkeley

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Professor William H. Dow, Chair
Professor David I. Levine
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Abstract

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Professor William H. Dow, Chair

Many cost-effective health products are underused in poor countries, although the burden from diseases that could benefit from these products remains high. Using community health workers (CHWs) to increase utilization of essential health products is a promising strategy, yet little is known about how best to structure such programs to maximize coverage. In this study, I examine two key features of CHW program design: 1) charging vs. free distribution of health products and 2) home delivery vs. client retrieval of health products. I measure the impact of these different strategies in the context of distribution of oral rehydration salts (ORS) and zinc—highly effective but widely underused treatments for child diarrhea. In addition, I examine the role of two barriers that could contribute to low ORS and zinc utilization: price and convenience. I use a four-armed, village-clustered, randomized design across 118 villages in Uganda to experimentally vary the price and convenience of accessing ORS and zinc from CHWs. Villages were randomized to one of the following three intervention groups or a control group: 1) A novel preemptive home delivery intervention (Free+Delivery) makes ORS and zinc free and conveniently available inside the home when a child comes down with diarrhea; 2) A preemptive Home Sales intervention makes accessing ORS and zinc conveniently available at the home, but not free; 3) A free upon retrieval intervention (Vouchers) makes ORS and zinc free but not convenient; 4) A control group has CHWs carry out their normal activities. This design allows me to evaluate the impact of these different distribution strategies as well as to examine the role of price (Free+Delivery vs. Home Sales) and convenience (Free+Delivery vs. Vouchers) in underuse of ORS and zinc. The first result is that Free+Delivery increased the share of cases treated with ORS (primary outcome) by 20 percentage points (36%) and ORS+zinc by 33 percentage points (106%), relative to the control group. Second, Free+Delivery increased ORS use by 12 percentage points (18%) and ORS+zinc use by 18 percentage points (40%) relative to Home Sales, suggesting that price is an important barrier to use. Third, I find no difference in use between Free+Delivery and Voucher groups, suggesting that convenience is not a key barrier to use. Fourth, among households where a diarrhea episode occurred, I find little evidence that Free+Delivery did a worse job of targeting or increased wastage relative to the other groups. Finally, I find that Free+Delivery is extremely cost effective from a donor perspective in terms of cost per case treated with ORS ($2.20) and cost per DALY averted ($64), relative to the status quo. When household out-of-pocket costs are considered, Free+Delivery is cost saving relative to all other groups, implying that this is the preferred distribution strategy. The results of this study suggest that price is an important barrier to ORS and zinc use in Uganda, that substantial gains in ORS and zinc coverage can be made if CHWs distribute the products for free as opposed to charging, and that free distribution is highly cost effective.

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1 Introduction

In many developing countries, illnesses for which we have long had prevention technologies and effective treatments available remain leading causes of death (e.g. diarrhea and bacterial pneumonia). As a result, one of the defining challenges for the global health community is to understand 1) *why* effective health products are underused and 2) *how* to increase use. Community health workers (CHWs) are increasingly relied on as a mechanism for increasing access to essential health products, however, there is substantial variation in the structure of CHW programs, and there is little evidence on how such programs should be structured to maximize coverage. For example, some CHW programs charge for health products, whereas others distribute products for free. Some CHWs distribute products to clients through home delivery, whereas others impose the cost of retrieval. In this study, I experimentally test the impact of different strategies of CHW distribution of diarrhea treatment in Uganda, which vary in the extent to which they impose monetary and retrieval costs to the household.

Diarrheal diseases are the second leading cause of death globally for children under five-years-old, with roughly 500,000 deaths annually (Liu et al., 2015). Death from diarrhea is particularly tragic since around 93% of deaths could be averted with the use of oral rehydration salts (ORS) (Munos et al., 2010). ORS effectively treats diarrhea induced dehydration, which is the underlying cause of most deaths (Cash et al., 1970; Pierce et al., 1969; Santosham, 1982; Spandorfer et al., 2005). In 1978, ORS was lauded as one of the most important medical advances of the 20th century by the medical journal *The Lancet* (Lancet, 1978) and since 1980, when ORS became widely available, there has been more than a two-thirds reduction in global deaths from diarrhea for children under five-years-old (Victora et al., 2000; Liu et al., 2012). Due to its low cost and high effectiveness, ORS is recommended by the WHO for all cases of child diarrhea regardless of illness severity (USAID, 2005). More recently, zinc was introduced as a recommended treatment for child diarrhea to compliment ORS after it was demonstrated to reduce illness severity and provide short term prevention benefits (Bhutta et al., 2000).

Despite the effectiveness of ORS and zinc in preventing death from diarrhea, utilization remains dangerously low, particularly in sub-Saharan Africa (SSA) (Forsberg et al., 2007; Pantenburg et al., 2012; Ram et al., 2008; Santosham et al., 2010; Liu et al., 2012; Sood and Wagner, 2014). In Uganda, only about 46% of diarrhea cases are treated with ORS (UDHS, 2011). Finding ways of increasing use of ORS is an essential step towards reducing child mortality in Uganda and throughout the region. With CHWs stationed in over 30,000 villages in Uganda, it is important to understand how best to work with these CHWs to increase ORS use.

Although there is an extensive body of medical literature assessing the health gains from ORS (Cash et al., 1970; Pierce et al., 1969; Santosham, 1982; Spandorfer et al., 2005; Munos et al., 2010) and identifying the problem of underuse (Forsberg et al., 2007; Pantenburg et al., 2012; Ram et al., 2008; Santosham et al., 2010; Liu et al., 2012; Sood and Wagner, 2014) there is little evidence on *why* ORS use remains low and what interventions effectively increase use. A recent systematic review by Lenters et al. (2013) found only 19 studies that assessed interventions to increase ORS use, and only three randomized controlled trials (RCTs). The authors concluded that most of the studies reviewed were of low quality and were skewed towards South Asia. As a result, much more evidence is needed on potential strategies for increasing ORS use, particularly in sub-Saharan Africa.

There are several potential explanations for why ORS use remains low. First, it is possible that people are unaware of the life-saving benefits of ORS (the *information barrier*). However, this is unlikely to be an important barrier since ORS has been widely available and socially marketed for over three decades, and awareness in Uganda is nearly universal (UDHS, 2011).

Second, ORS could be too expensive. Several recent RCTs have demonstrated that even highly subsidized prices lead to large reductions in demand and subsequent use of other health products (see Kremer et al. (2011a) for a review). Although ORS is free at public health clinics, over half of caretakers seek care for diarrhea in the private sector, where they are required to pay for ORS (UDHS, 2011). Moreover, many community health workers in Uganda sell ORS at a subsidized price. In our study villages, over 70% of caretakers that use ORS pay for it. Since ORS does not provide an *observable* benefit to the child (no effect on volume or duration of diarrhea), caregivers might undervalue ORS and might not be willing to pay the small price (USD $0.30 per treatment course) (the *price barrier*). Moreover, caregivers in poor communities might be liquidity and credit constrained, and thus might not have the cash-on-hand to pay the small fee. This suggests that free distribution of ORS could increase use.

Third, it can be an inconvenience to visit health facilities or drug shops to retrieve ORS, particularly since most children have diarrhea many times throughout the year. Several recent studies have found that demand for other health products is sensitive to the convenience of accessing them (Thornton, 2008; Banerjee et al., 2010; Kremer et al., 2011b). Many caretakers in Uganda are required to walk long distances to retrieve ORS. Even for those living in relatively close proximity to ORS distributors, cognitive biases such as time-inconsistent preferences, inertia, or limited attention could hinder ORS retrieval (the *convenience barrier*). This suggests that making ORS more convenient could increase use.

I designed a series of interventions that experimentally vary the price and convenience of accessing ORS and zinc from CHWs. The experimental design allows me to compare the effectiveness of different CHW distribution strategies and to examine the role of price and convenience as barriers to ORS use. I use a four-armed, village-clustered, randomized design (three intervention groups and a control group) to assess the individual and combined impact of overcoming price and convenience barriers on ORS use (primary outcome). The interventions were carried out by Community Health Promoters (CHPs), a CHW program implemented by BRAC Uganda. A novel *preemptive home delivery* intervention (Free+Delivery) makes ORS and zinc free and conveniently available inside the home when a child comes down with diarrhea. Under this intervention, CHPs were instructed to delivery ORS and zinc for free to all households with a child under five-years-old at the beginning of the study period. A *preemptive home sales* intervention (Home Sales) makes accessing ORS convenient but not free. Under this intervention, CHPs were instructed to visit all households with a child under five-years-old at the beginning of the study period and offer to sell ORS and zinc at the market price. A *free upon retrieval* intervention (Vouchers) makes ORS and zinc free but not convenient. Under this intervention, CHPs were instructed to visit all households with a child under 5-years-old at the beginning of the study period and provide a voucher that could be redeemed for free ORS and zinc from the CHP's home. Finally, a control group had CHPs carry out their normal activities. This design allows for an impact evaluation of competing CHW distribution strategies as well as to examine the role of price (Free+Delivery vs. Home Sales) and convenience (Free+Delivery vs. Vouchers) in underuse of ORS.

The first result is that Free+Delivery increased the share of cases treated with ORS by 20 percentage points (36%) and ORS+zinc by 33 percentage points (106%), relative to the control group. Second, Free+Delivery increased ORS use by 12 percentage points (18%) and ORS+zinc use by 18 percentage points (40%) relative to Home Sales, suggesting that price is an important barrier to ORS and zinc use. Third, there was no difference in treatment use between Free+Delivery and Voucher groups, suggesting that convenience was not a key barrier to use. These results suggest that free distribution by CHWs (either through Free+Delivery or Vouchers) can substantially increase ORS and zinc use. I use several strategies to validate self-reported outcomes including ORS packet counting, placebo tests (negative controls), and shorter recall periods, which help to solidify these main results.

In addition to the primary analyses described above, I conduct several additional analyses investigating other important impacts of these interventions. First, in addition to measuring the impacts on ORS and zinc use, I examine the effects on time to treatment initiation. Death can occur very quickly after the start of a diarrhea episode, and the WHO recommends immediate initiation of both ORS and zinc. I find that Free+Delivery increased the share of cases that started ORS on the same day as the start of a diarrhea episode by 19 percentage points (96%) relative to a control group, by 19 percentage points (95%) relative to Home Sales, and by 7 percentage points (24%) relative to Vouchers. Therefore, Free+Delivery not only increase coverage of ORS, but has the additional benefit of reducing the time to ORS initiation.

Second, in addition to understanding the impact of these CHW interventions, a related question is how home ORS storage impacts ORS use. If home storage significantly increases ORS use, other programs could also focus on ensuring households have ORS stocked. For example, maternal and child health clinics could distribute ORS for future use at routine check-ups. To measure the impact of home ORS storage on use, I use random group assignment as an instrument for having ORS stored in the home prior to a diarrhea episode. I find no evidence that home storage of ORS increases use relative to retrieval from the CHP's home, however, coefficients are large and positive, and confidence intervals are wide, which does not allow me to rule out large effects of home storage.

Third, I investigate the role of price and convenience in targeting ORS to the most vulnerable cases of diarrhea (those at higher risk of mortality from diarrhea). Proponents of charging for health products argue that imposing prices better targets the most vulnerable beneficiaries, whereas free distribution could lead to expanded coverage among those with less need (PSI, 2003). By this logic, it is possible that free ORS delivery expands coverage to less vulnerable children (i.e. children/cases with lower mortality risk). Several studies have assessed the role of price in targeting health products to those most likely to benefit and there is little evidence that free distribution expands coverage to those with less need. Kremer and Miguel (2007) find that parents of children with higher levels of parasitic worms are no more likely to purchase deworming treatment. Cohen and Dupas (2010) find that pregnant women who are anemic (a sign of a prior malaria case) are no more likely to purchase a mosquito net than non-anemic women. Ashraf et al. (2010) and Kremer et al. (2011c) find that households with young children (who are more vulnerable to death from diarrhea) are not willing to pay more for point-of-use water treatment. This study is the first to assess the role of both prices and convenience in terms of targeting subsidized diarrhea treatment to the most vulnerable. Relative to the control group, I find that Free+Delivery increased ORS use by *more* for children under 12 months, when the mortality risk is higher, and there is no difference in the effect of Free+Delivery for more severe cases (blood in the stool and/or concurrent fever). Moreover, retrieval costs do not appear to target more vulnerable cases relative to Free+Delivery. This suggests that concerns that Free+Delivery will simply expand access to less vulnerable children are unwarranted.

Fourth, I investigate the trade-offs associated with each of the three interventions in terms of increasing coverage and targeting ORS to compliers (those with high propensity to use ORS for its intended purpose). Free+Delivery could do a worse job of targeting subsidized ORS to compliers than Vouchers or Home Sales, which could result in more product wastage. Although several studies have shown that charging for health products reduces coverage, there is mixed evidence on how price functions as a mechanism for screening out non-compliers (Cohen and Dupas, 2010; Ashraf et al., 2010; Kremer et al., 2011a). Moreover, very few studies have directly compared monetary prices, retrieval costs, and free delivery in terms of efficient allocation of subsidies (Dupas et al., 2016), and this work is the first to do so in the context of diarrhea treatment. I find that, among households with a diarrhea episode, there is little evidence that Free+Delivery does a worse job of targeting to compliers than the other groups. However, among households with no case of diarrhea, take-up of ORS in the Free+Delivery group was much higher than the other groups, leading to more unused ORS after one month. This suggests that Free+Delivery could lead to more product wastage than the other groups if some portion of the unused ORS never gets used.

Finally, I complement the resource targeting analysis described above with a cost-effectiveness analysis, which provides a more complete picture of efficient resource allocation. When only considering implementer costs, I find that Free+Delivery costs only \$2.20 for each additional case of diarrhea treated with ORS relative to the status quo and \$2.66 relative to Home Sales. Moreover, I find that Free+Delivery costs only \$64 and \$77 per DALY averted, relative to the control group and Home Sales, respectively. Finally, when also considering out-of-pocket payments made by the households (e.g. treatment costs, clinic costs, and cost of time), I find that free-delivery is cost-saving relative to all other scenarios. This suggests that Free+Delivery is the preferred strategy of ORS distribution.

This study provides evidence that price is an important barrier to ORS and zinc use in Uganda and that substantial gains in ORS and zinc coverage can be made if CHWs distribute these treatments for free rather than charging. Moreover, free distribution is highly cost effective and home delivery is the most efficient way to distribute free ORS and zinc. The rest of this dissertation proceeds as follows. Sections 2 and 3 discuss the background on CHW programs and policies around ORS use, sections 4 and 5 provide a conceptual framework that highlights the mechanisms through which the interventions can be expected to increase ORS use, section 6 describes the research design and strategy, section 7 describes the analysis of treatments effects, section 8 describes the analysis of targeting to compliers, section 9 describes the cost-effectiveness analysis, section 10 provides a discussion of the findings, and section 11 concludes.

2 Background: CHW Programs

2.1 Overview of CHW Programs

Due to the shortage of formally trained health workers, CHWs are a large part the health care system in many developing countries. Nearly all countries in sub-Saharan Africa and South Asia have a CHW program in place. CHWs are generally members of the community who live near the households they serve. Most CHWs are volunteer workers, however a small number receive financial and/or non-financial compensation. There is substantial evidence that CHW programs reduced mortality and morbidity (see Christopher et al. (2011) for a review).

The vast majority of CHW programs are funded by national health budgets. Government sponsored CHWs are present in over 30,000 villages in Uganda. These government CHW programs generally provide services and products for free. However, there is growing support for an entrepreneurial model, where CHWs purchase health products at a highly subsidized price and sell the products back to their community for a profit (e.g. BRAC and Living Goods). These models are more financially sustainable and provide some income to the health worker. A recent randomized trial found that introduction of such a model reduced child mortality by 27% relative a control group (Bjorkman Nyqvist et al., 2016). However, it is unclear if the entrepreneurial aspects of the program were driving the effect, or rather if simply having a community health worker in the village providing services for free would have achieved similar results. In this study, I work with BRAC Uganda, which implements an entrepreneurial community health promoter (CHP) program, to help identify whether free distribution of ORS and zinc can achieve better outcomes than the entrepreneurial model of charging for ORS and zinc.

2.2 Overview of BRAC's CHP Program

BRAC has CHP programs across 12 countries and manages over 3,000 CHPs across 70 districts in Uganda. CHPs are community members who are hired by BRAC to sell essential health products to others in the village. Products are purchased by CHPs from BRAC at a subsidized price and sold back to community members for a profit (usually at the market price). CHPs are also trained to provide very basic primary care (e.g. helping to administer simple treatments) and health education, but they do not have any formal training. Each month CHPs attend a refresher training session at the BRAC office, at which point they refill their supply of health products. CHPs sell an array of products such as ORS, zinc, water treatment, bed nets, malaria treatment, and other basic household items (e.g. soap). They are instructed to travel door-to-door to offer these services, however, qualitative evidence and household surveys suggest that much of the sales are made at the CHP's home rather than door-to-door. During visits, CHPs are also instructed to provide basic health education (e.g. case management of common illnesses and hand washing).

3 Background: ORS Use

3.1 Overview of Policy Environment Around ORS Use

Although most developing country governments and international aid organizations include expansion of ORS coverage as a stated goal, there is little evidence on what interventions are effective at achieving this goal. There were substantial efforts to increase ORS use in the 1980s and 1990s, and over 100 countries had ORS promotion programs in place by 1988 (WHO, 1990). These programs appear to have been successful, increasing use of ORS or other forms of oral rehydration therapy (ORT) from close to 0 in 1980 to around 40% in 1990 (Forsberg et al., 2007). Moreover, awareness of ORS was nearly universal. However, most programs aimed at increasing ORS use were comprised of many different interventions (e.g. provider training, social marketing, supply chain management, etc.) making assessment of the impact of each individual mechanism difficult. Moreover, after the big push to increase ORS use during the 1980s and 1990s, the share of diarrhea cases that are treated with ORS has leveled off at around 40%, suggesting that novel interventions are needed to overcome this "last mile" problem.

In Uganda, the ministry of health (MoH) and other international organizations recognized the need for intervention and have programs in place aimed at increasing ORS use. In 2001, the MoH started the Village Health Team project, where community members are assigned to act as a liaison between rural areas and the health system by providing basic health care needs (including ORS distribution and diarrhea education). The Clinton Health Access Initiative (CHAI) in Uganda focuses on reducing the price of ORS and zinc in the private sector, where many people seek treatment. USAID funds the Strengthening Health Outcomes through the Private Sector (SHOPS) project, which focuses on increasing provision of ORS and zinc in the private sector. Living Goods and BRAC both have CHP programs, which focus on increasing knowledge of and access to ORS by having community members sell the products to their fellow villagers. Plan International focuses on ensuring sufficient supply of ORS and zinc in rural areas. Although there is an immense amount of effort being put towards interventions aimed at increasing ORS use, it is not clear what the remaining barriers to ORS are, and which interventions are likely be effective. Below, I outline the evidence in the three areas where most of the recent empirical research has focused; provider interventions, community interventions, and social marketing interventions.

3.2 Provider Interventions

There is substantial evidence that health providers, particularly in the private sector, fail to provide ORS when presented with a case of diarrhea (Sood and Wagner, 2014; Wagner et al., 2014; Mohanan et al., 2015). However, there is little evidence demonstrating why such under-provision in the private sector occurs. Wagner et al. (2014) find that private providers in India are less likely to directly distribute ORS and suggest that making ORS more convenient to private sector patients could increase take-up. Friedman et al. (2015) randomly assigned drug shop sellers in Ghana to receive text messages encouraging ORS provision. Although drug sellers who received the messages reported increased ORS provision, their observed ORS provision practices did not change. Clearly, much more work is needed in order to understand why private providers under-provide ORS and how to increase provision. However, many caretakers (potentially the most vulnerable) do not seek care from a provider at all and therefore would not benefit from provider focused interventions.

3.3 Community Interventions

Several community interventions have shown to be successful at increasing ORS use. In a recent cluster RCT in Myanmar, Aung et al. (2014) found that a social franchising intervention that provided community education and community supply of ORS and zinc increased ORS and zinc use from 1.8% to 13.7%. Awor et al. (2014) use a quasi-experimental design to evaluate an integrated community case management (ICCM) intervention in Uganda that trained private drug shops, provided supply of ORS, and provided education to community members. They found that provision of ORS and zinc increased 12-fold as a result of the intervention. An unpublished study that experimentally evaluated the impact of the Living Goods and BRAC CHP program (the same program that will carry out our intervention) found that ORS use increased from 33% to 39% as a result of the CHP program.

There is also evidence that introduction and promotion of zinc in a community as a compliment to ORS results in increased ORS use (Lenters et al., 2013). Baqui et al. (2004) randomly assigned introduction of zinc to communities in Bangladesh and found that access to zinc increased use of ORS. Bhandari et al. (2008) found similar results in India.

3.4 Social Marketing Interventions

There are several observational studies that assess the impact of social marketing and mass media campaigns on ORS use. Kassegne et al. (2011) found that ORS use increased from 20% to 30% after a PSI sponsored social marketing campaign in Burundi. Rao et al. (1998) found that ORS use in India during a time when the government promoted ORS through mass media increased more for mothers that had exposure to the campaign via radio, television, or cinema. Lenters et al. (2013) reviewed several studies in a meta-analysis assessing the impact of social marketing and mass media campaigns on ORS use and found a pooled risk ratio of 2.05, although this estimate was not statistically significant.

3.5 Summary

Increasing ORS use appears to be an important part of many national health agendas, yet we know very little about what effectively achieves this goal. Provider interventions appear to have potential, although the evidence is lacking. Community and social marketing interventions have shown to be effective, but neither appear to achieve the desired coverage rates, which suggest they alone are not sufficient. Not only does the current study evaluate the impact of different strategies of increasing ORS use, but it isolates for the mechanisms at work, which will help guide future ORS promotion interventions. Next, I provide a conceptual framework for the mechanisms and specific channels through which each intervention is expected to work.

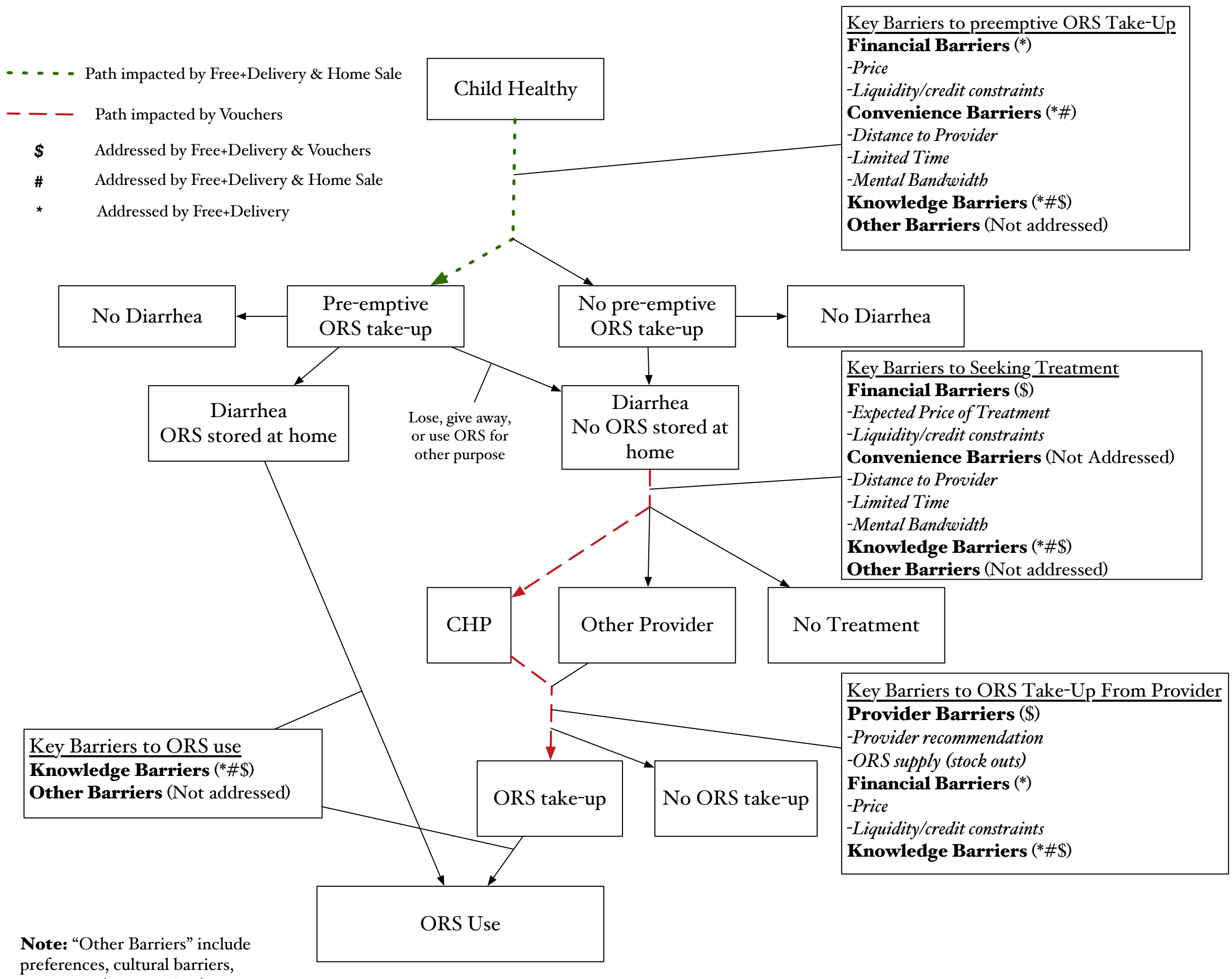
4 Conceptual Framework: The Decision to Use ORS and Intervention Mechanisms

Each of the three interventions is likely to affect ORS use through different channels. The flow diagram below portrays the caretaker's choice to use ORS to treat their child's diarrhea and the various barriers that she faces at each stage. The child starts off healthy and during this time, caretakers can either acquire ORS for later use (preemptive take-up) or not acquire ORS. The decision to acquire ORS for later use has many potential barriers including financial barriers (prices and liquidity/credit constraints), convenience barriers (distance to provider, limited time, and limited attention), knowledge barriers, and other barriers not addressed by this study (e.g. low perceived probability of diarrhea, preferences for other treatments, and cultural barriers). If the caretaker decides to take-up ORS pre-emptively and the child becomes ill with diarrhea, then most caretakers will have ORS stored at home upon diarrhea initiation (although some could lose or give away the product). With ORS stored at home when diarrhea begins the choice to use ORS is fairly easy, only impeded by barriers unrelated to price and convenience (i.e. knowledge, low perceived severity of illness and "other" barriers described above).

On the other hand, if caretakers do not preemptively acquire ORS and the child comes down with diarrhea, then they have to make a series of complex choices and face an array of potential barriers after the child comes down with diarrhea, before acquiring and using ORS. First, they choose whether/where to seek treatment for the child. For simplicity, we assume that caretakers can either seek treatment from a CHP, another provider, or choose not to seek treatment. Seeking treatment after diarrhea initiation has the same barriers as seeking treatment preemptively, except that at this point the child might be in danger, and treatment should be started immediately. If the caretaker decides to seek treatment, receipt of ORS is not guaranteed and is subject to provider barriers (provider recommendation and supply), as well as financial and knowledge barriers. As mentioned above, many providers in Uganda do not provide ORS when presented with diarrhea. If the caretaker does receive ORS from the provider, she then has the choice of using the ORS to treat the child.

This diagrams highlights an important point. Preemptive take-up of ORS makes the decision

Flow diagram of ORS take-up and use



Note: "Other Barriers" include preferences, cultural barriers, poor taste, low perceived probability diarrhea and others.

to use ORS when the child comes down with diarrhea much less complicated with far fewer barriers and hassle costs than if ORS is acquired after diarrhea initiation. Caretakers that do not take-up ORS pre-emptively have to make several complex decisions and face many barriers to ORS take-up and use after the becomes ill—e.g. the caretaker could avoid treatment because the provider is too far away or they are busy with other activities, the provider could recommend an antibiotic instead of ORS or they could have a stock out. By preemptively acquiring ORS, the caretaker bypasses barriers to seeking treatment once the child becomes ill and barriers to receiving ORS from a provider.

Each of our interventions will alter the likely pathway taken by the caretaker in different ways by addressing a different set of barriers (although all interventions will address the knowledge barrier).

Free+Delivery
The affected pathway for free preemptive home-delivery is indicated with a green dotted line and the barriers addressed are indicated by * in the diagram above. This intervention will increase the likelihood of preemptive ORS take-up. Financial barriers, convenience barriers, and knowledge barriers will all be addressed. Since most households will have ORS stored at home when the child comes down with diarrhea, ORS use is only hindered by barriers unrelated to price, convenience, and knowledge.

Home Sales
Preemptive home visits with an offer to sell ORS will alter the average caretaker's preferred path in a similar way as Free+Delivery (also indicated by a green dotted line), however it will not overcome all of the same barriers (indicated by # in the diagram above). Only convenience and knowledge barriers are addressed, leaving financial barriers as impediments.

Vouchers
Free distribution of ORS upon retrieval from the CHP's was expected to have a larger effect on the decision making process after the child comes down with diarrhea, since I expected most caretakers to wait to redeem vouchers until the child comes down with diarrhea.[1] The affected pathway for this intervention is indicated with a red dashed line. This intervention will affect ORS take-up in two ways. First, the caretaker will have been informed that the CHP has free ORS available, which will shift the provider decision pathway towards seeking treatment from the CHP. This will also address financial barriers to seeking treatment, although it will not address convenience barriers. Second, upon seeking treatment from the CHP, financial barriers will no longer be present since ORS will be provided for free. Moreover, the CHP does not provide other treatments aside from ORS and zinc, and our intervention will ensure she is fully stocked, addressing the provider barriers. This shifts the distribution of treatment seeking towards a provider with higher probability of providing ORS.

5 Conceptual Framework: Evidence of Barriers

The barriers to ORS use that are addressed by the interventions are all related to either poor knowledge, price, convenience, or provider barriers. Although the evidence for some of these barriers is limited in the context of ORS use, there has been a substantial amount of work identifying and addressing these barriers in the context of other health products. Below I highlight the evidence for each of these barriers and how the evidence relates to ORS.

[1] It turned out that a large share of caretakers redeemed their vouchers preemptively.

5.1 Knowledge

A frequently offered explanation for low ORS use is that caretakers are unaware of the product or its benefits. This suggests that informing caretakers of the life-saving benefits of ORS would be effective at increasing take-up. Providing information about healthy behaviors has had success in terms of behavior change in the past (Dupas, 2011; Kremer et al., 2011a) and this thinking has led to many social marketing campaigns aimed at spreading awareness of ORS (Lenters et al., 2013; Kassegne et al., 2011). Mass information campaigns in the 1980s are often credited with the high ORS usage rates in Bangladesh (Smillie, 2009) and the large reduction in diarrhea mortality in Egypt (Levine, 2004). Moreover, for the last 3 decades there has been a concerted effort to increase awareness of ORS to treat child diarrhea in Uganda and knowledge generation about proper diarrhea treatment is a key role of CHPs. It appears that this effort has been very effective, evidenced by near universal awareness of ORS across the country. In the most recent Demographic and Health Survey, over 90% of mothers of children under-5 were aware of ORS (UDHS, 2011). Similarly, among the population of the present study, where CHPs have already been working to increase ORS knowledge, over 96% of mothers had heard of ORS (baseline survey). Moreover, over 85% of the mothers in our sample had used ORS to treat diarrhea at some point in the past. However, this knowledge of ORS does not seem to translate into sufficient use, as only 46% of diarrhea cases in the 2 weeks prior to data collection were treated with ORS (UDHS, 2011). Two points emerge from this discussion. First, awareness of ORS is reaching a ceiling and there is little room for increased awareness. Second, awareness of ORS is not enough to results in sufficient ORS use. Therefore, in order for information to affect ORS use, it must be provided in a strategic way that changes preferences or beliefs about ORS, a much more difficult task then simply raising awareness about the product. In this study, CHPs reinforce ORS and zinc knowledge, however, most households had already received this information. I hypothesized that the information provided through this study would have little effect on ORS use and I did not design the study to isolate this effect.

5.2 Price

Another potential reason for under-use of ORS is unwillingness-to-pay even the small, often subsidized price. Although ORS is freely available at public health clinics, most caretakers seek care in the private sector where they are required to purchase ORS. Moreover, many community health workers (including BRAC's CHPs) charge for ORS.

Several recent RCTs show that even highly subsidized prices can result in a substantial reduction in take-up and use of preventive health products relative to free distribution. Kremer and Miguel (2007) found that free distribution of deworming medication to Kenyan children increased take-up from 18-75% relative to a small fee. Cohen and Dupas (2010) found that take-up of bed nets in Kenya falls by 60% when the price increases from 0 to $0.60. Ashraf et al. (2010) found that take-up of point-of-use water treatment in Zambia falls by 30% when price increases from $0.09 to $0.25. Similarly, Dupas et al. (2016) found that take-up of point-of-use water treatment in Kenya falls by 38% and use falls by 62% when the price increases from zero to a 50% discount. Kremer et al. (2011c) found that a majority of households use chlorine for water treatment in Kenya when provided for free, but only 10% use it at the market rate. Dupas et al. (2011) found that chlorine use increased nearly 3 fold when it was provided for free relative to a 50% discount. Spears (2009) found that take-up of hand washing soap in India falls from 84% to 13% when the price changes from 3-15 rupees. Taken together, these studies suggest that poor people in developing countries are very sensitive to prices of preventive health products, and even highly subsidized prices can substantially reduce take-up and use.

Although people appear to be extremely sensitive to prices of preventive products, demand for remedial health products appears to be relatively price-inelastic. For example, Cohen and Dupas (2010) show that increasing the price of an antimalarial treatment course for young children by 250%, from US$0.30 to $1.5, does not reduce the share of households buying the treatment (about 32%). This discrepancy in price sensitivity for curative products and preventive products is often explained using concepts from behavioral economics such as present bias; the benefits from curative products pay off immediately whereas the benefits of preventive products, although a smart investment with high returns, pay off far into the future. Since ORS is only recommended once a child becomes ill with diarrhea, it could be thought of as remedial. Therefore, it is possible there is less price sensitivity than found in the above studies which focused on primary prevention products. However, ORS could also be thought of as secondary prevention (managing an illness to avoid poor outcomes) instead of curative and has several similar features as the primary prevention products from past studies. First, ORS has limited observable effects on the main diarrhea symptoms (i.e. volume and duration of episode), and instead treats dehydration to prevent death. Therefore, similar to primary preventive products, the benefits of ORS (keeping the child alive and hydrated) might go unnoticed since the diarrhea persists. On the other hand, malaria treatment directly affects the main symptoms of malaria. Second, ORS initiation is recommended immediately after the diarrhea episode begins, prior to the child becoming dehydrated. Therefore, ORS is *actually* recommended as prevention of dehydration. Finally, and most importantly, similar to preventive products, ORS use remains low although there appear to be substantial returns to investment.

Prior to this study, it was unclear if ORS would fall more in line with preventive or curative products in terms of price sensitivity. There is only poor evidence on how sensitive caretakers are to the price of ORS, and no experimental evidence. Aung et al. (2013), using a survey in Myanmar, find that less than 25% of caretakers are willing to pay the market rate for ORS. Several other studies have documented the impact of community based interventions to increase ORS use, some of which include free distribution (see Das et al. (2013) for a review). However, no studies have isolated for the impact of price.

5.3 Convenience

A third potential barrier to ORS use is convenience of access or hassle costs. Many mothers are required to walk long distances or pay high transport costs to reach their nearest clinic. Time constraints may lead caregivers to rationally choose to only make the long journey if a case becomes “severe”, at which point it could be too late. Even when distributors are easily accessible, concepts from behavioral economics such as time-inconsistent preferences, inertia, or limited attention could hinder ORS retrieval.

Several studies suggest that distance and inconvenience can be important barriers to take-up. Thornton (2008) found that distance to HIV testing centers was a key barrier, an even larger barrier than price, to retrieval of HIV test results in Malawi. Kremer et al. (2011b) found that individuals are only willing to walk 3.5 minutes further to collect water from a protected spring that produced clean water as opposed to retrieving contaminated water from an unprotected well. Banerjee et al. (2010) found that small incentives (less than a day’s wage) resulted in much greater willingness to travel to immunization camps. Taken together, these studies demonstrate that distance and convenience are important factors in take-up of health services, and that making products more convenient could increase utilization.

Although there is no direct evidence on how convenience of ORS affects use, several studies find that community interventions that increase ORS availability improved coverage (Das et al., 2013). However, other factors associated with community distribution could be driving these effects.

5.4 Provider Barriers and Default Treatment Options

Even if caretakers travel the long distance to a faraway health provider or overcome inertia to visit a more convenient provider, ORS take-up is not certain. Caretakers face an array of treatment choices in addition to ORS and zinc. Moreover, treatment choices are often left to the provider's discretion and although most providers are aware that treatment guidelines include ORS, they frequently provide alternatives such as antibiotics or antidiarrheals instead, both of which are normally unnecessary and potentially harmful (Sood and Wagner, 2014; Mohanan et al., 2015). In 2011, Only 50% of children in Uganda who visited a health provider for diarrhea care received ORS, and under 10% received zinc (UDHS, 2011). Although there is limited evidence to help understand why providers fail to give caretakers ORS, it is often conjectured that private providers have a preference for selling more profitable products. Having ORS delivered and stored in the household or freely available from the CHP's home will eliminate the need to visit a provider for treatment. Instead, ORS and zinc will become the default treatment option. There is a substantial literature demonstrating the power of defaults (White and Dow, 2015; DellaVigna, 2009), and we expect that making ORS and zinc the default choice will both increase use of ORS and zinc and reduce unnecessary and potentially harmful use of antibiotics.

6 Study Design

6.1 Overview

This study uses a cluster randomized controlled trial design. We worked with BRAC to select 6 branches to enroll in the study. Branches are local offices used to coordinate all of BRAC's operations in the surrounding villages. We then enrolled all villages affiliated with the selected branches where a CHP was active (about 20 per branch) resulting in 118 villages. All branches were within a 2-hour drive from Kampala, Uganda's capital city, and most villages were considered peri-urban (See Figure 2). Study sites were chosen based on 3 criteria: 1) high diarrhea prevalence, 2) branch managers are willing to participate and help with coordination, and 3) close proximity to Kampala (due to budgetary constraints). The interventions took place at the village level, since one CHP is dedicated to serve an entire village. Although some villages were in close proximity of each other, CHP catchment areas did not overlap. Each CHP/village was randomly assigned to one of four groups.

Control — Status Quo: No intervention took place and CHP's carried out their normal activities. Caretakers had standard access to ORS and zinc at local health facilities and pharmacies. At baseline, most caretakers obtained ORS from a private seller (43%) or a public clinic (20%). About 1/3 obtained ORS from the CHP and almost all retrieved ORS after the child came down with diarrhea. Less than 10% of caretakers had ORS stored in their home prior to a diarrhea episode. Over 70% of caretakers that used ORS at baseline paid for it.

Preemptive Home Delivery (Free+Delivery): CHPs were instructed to visit all of the households in their catchment area that contained a child under 5-years-old (roughly 100 households) at the beginning of the study and give caretakers two packets of ORS and ten tablets of zinc per child under-5 (free of charge) to store in their homes. In addition, CHPs were instructed to provide the standard information on ORS and zinc (see Appendix Figure 1).

Preemptive Home Sales: CHPs were instructed to visit all of the households in their catchment area that contained a child under 5-years-old at the beginning of the study and offer to sell ORS and zinc to caretakers at the market price (USD$0.50 per treatment course for two packets of ORS and ten tablets of zinc). CHPs were allowed to retain the money from any sales. CHPs were also instructed to provide the standard information on ORS and zinc.

Free Upon Retrieval (Vouchers): CHPs were instructed to visit all of the households in their catchment area that contained a child under 5-years-old at the beginning of the study and provide caretakers with one voucher per child under-5 that could be redeemed at the CHP's home for two packets of ORS and 10 tablets of zinc. CHPs were also instructed to provide the standard information on ORS and zinc. On average it takes about 10 minutes to walk to the CHP's home.

Random assignment was stratified by BRAC branch (5 villages in each group per branch) and baseline ORS use. Baseline ORS use was split into quintiles within each branch and random assignment ensured that 1 village from each quintile-branch was in each of the 4 groups. I used the *randtreat* package in Stata 14 to carry out this process. Figure 1 displays the CONSORT flow diagram for the study.

The main mechanisms of the interventions that would be expected to affect ORS use are preemptive home access to ORS, free distribution of ORS, information given during the CHP visits, and increased ORS supply for the CHP (the latter two are constant across treatment arms).

Mechanisms At Work

	Preemptive Home Access	Free Distribution	Information + Increased Supply
Control	no	no	no
Free+Delivery	yes	yes	yes
Home Sales	yes	no	yes
Vouchers	no	yes	yes

Comparing Free+Delivery to the control group provides an estimate of the impact of the suite of mechanisms in effect simultaneously relative to the status quo. Comparing Free+Delivery to Home Sales provides an estimate of the price effect, since the only difference between these groups is that CHPs in the Home Sales group were instructed to sell products at the door and CHPs in the Free+Delivery group were instructed to deliver products for free. All other key mechanisms are held constant. Comparing Free+Delivery to Vouchers provides an estimate of the convenience effect, since the only difference between these groups is that CHPs in the Vouchers group were instructed to distribute ORS from their homes, whereas CHPs in the Free+Delivery group were instructed to deliver ORS to the household pre-emptively. All other key mechanisms were intended to be held constant.

Other potential mechanisms include CHP training, increased salience, and changes in CHP effort. CHPs were all given the same training on ORS and zinc use, and therefore the training effect was constant across treatment arms. However, salience and effort could be different across treatment arms. Free distribution or home delivery of ORS and zinc could signal to caretakers that these treatments are particularly important. Therefore, the salience effect could be stronger in the free distribution groups (Free+Delivery and Vouchers). I hypothesized that CHP effort would be stronger in the Home Sales group, since this group had an extra financial incentive to distribute treatments, since they were allowed to keep the revenue. However, as I will discuss later, the opposite was true. CHPs assigned to Home Sales actually expended less effort. I will address the implications of differential CHP effort and how that complicates estimates of the price-effect in Section 7.5.

6.2 Intervention Training

CHPs that were assigned to one of the treatment groups were asked to attend a short training session at the local BRAC office. During the training, CHPs were given instructions on how to carry out the intervention to which they were assigned. The research team also provided a refresher training on the best practices for treating diarrhea, although all CHPs had already received this training from BRAC. The trainings for the three different interventions were conducted separately, and CHPs were asked not to discuss the training with any of the other CHPs. Trainings were structured to be identical across treatment groups aside from instructions on ORS and zinc distribution. Below is a summary of the instructions provided to CHPs during the trainings (same order for each intervention):

1. Visit all households with child under-5
2. Ask for main caretaker
3. Intervention Specific [provide free ORS+zinc/offer to sell ORS+zinc/provide voucher]
4. Provide standard information on using ORS and zinc (show caretaker flier, Appendix Figure 1)
5. Re-visit a household if primary caretaker is not home
6. Visit closest households first
7. We will check to make sure these tasks are followed appropriately
8. We will pay you 12 USD to make these household visits (half now, half in one month after verification of intervention)
9. Start immediately
10. Should take about 3 days
11. Don't discuss this with other CHPs
12. Please keep any remaining ORS and zinc for our records

The order of the instructions was kept the same across all interventions and item (3) was the only area where the instructions differed. CHPs in the Home Sales arm were instructed to sell each packet of ORS for \$0.15 and each packet of zinc for \$0.30 (the market price for each). Item (8) was intentionally left vague. Although there was no formal method for monitoring or enforcing CHP activities, we wanted them to know that the research team would follow-up to ensure the intervention was carried out. We did not have the means to make payments conditional on activities being carried out appropriately and we ultimately provided the payments to all CHPs that we trained.

After the training was completed, all participants were given a box filled with two ORS packets and ten zinc tablets per child under-5 in their catchment area. To estimate the number of children in the catchment area, we used the reported number of all households and assumed that 60% had a child under-5. Conditional on having at least one child under-5, we assumed households had 1.8 children under-5 ($HH * .6 * 1.8$) (UDHS, 2011). CHPs were estimated to be responsible for an average of 88 households with a child under-5 and were given an average of 291 packets of ORS and 145 strips of zinc (10 tablets per strip). CHPs received the same quantity of ORS and zinc regardless of intervention group assignment.

Of the 88 CHPs requested to attend a training session, 86 CHPs were actually trained. In two villages, the CHP had quit and a new CHP had not yet been hired, both in the Free+Delivery group. Our main analysis includes all 118 CHPs, which preserves the benefits of random assignment, but will provide a lower bound of the impact of the Free+Delivery intervention.

6.3 Sampling and Data Collection

After enrollment of CHPs but prior to random assignment, we had CHPs create a list of all households in their catchment area with a child under-5, which was used as the sampling frame. After the village listing, we conducted a baseline survey, where we visited the 40 closest households on the list to the CHP's home. One month after the intervention occurred, we conducted an endline survey, where we visited the 80 closest households on the list with a child under-5. The baseline survey was used primarily to assess pre-intervention balance and to construct village level covariates to adjust endline results. We chose to visit only 40 households at baseline to preserve our budget. If a village had less than 80 households, we conducted a full census. Although our sample might not be representative of the entire population in larger villages, it will be representative of the households most likely to benefit from the intervention.

At both baseline and endline, the interviewers asked the main caretaker whether a child had a diarrhea episode in the last 4-week. For the roughly 1/3 of households for which a child did have a diarrhea episode, the caretaker was asked a series of question about how this case was managed as well as about prior diarrhea treatment behavior, knowledge about case management, and other relevant characteristics about the households, caretaker, and child. Caretakers that did not care for a recent diarrhea episode completed only a short survey asking about take-up of ORS+zinc and contact with the CHP. Since I am primarily interested in treatment of child diarrhea, only children with a recent episode are included in my main analysis. Analyses that assessed ORS take-up included all households. Since a different set of children had an episode of diarrhea at baseline than at endline, we do not analyze a panel of children, but rather a repeated cross-section (or a panel of villages).

The research team surveyed 4,742 caretakers at baseline, of which 1,537 cared for a child with a case of diarrhea in the last 4 weeks (32%). Since some caretakers cared for multiple cases of diarrhea, this provided data on 1,770 cases at baseline. The team surveyed 7,949 caretakers at endline, of which 2,122 cared for a child with a case of diarrhea (27%). This resulted in data on 2,363 cases at endline.

My power calculations assumed 80 households per village at endline, and I was powered to detect an 11-14 percentage point increase in ORS use between groups with power of 0.8. Based on the characteristics of the final sample, I have the power to detect a 12 percentage points increase from the control group mean of 56% of cases treated with ORS.

7 Impact On Diarrhea Treatment Outcomes

This sections examines the effect of the three interventions on diarrhea treatment outcomes. Below I discuss the questions addressed, the methods used, and the results pertaining to diarrhea case management.

7.1 Research Question

The study was designed to answer an array of research questions, all of which were pre-specified in a pre-analysis plan that was registered at the American Economic Association RCT Registry (registry number AEARCTR-0001288). All analyses from sections 7 and 8 were outlined in this pre-analysis plan, with the exception of sections 7.5, 7.6, and 7.7, which were exploratory. Below, I outline the primary, secondary, and tertiary questions.

7.1.1 Primary Research Questions

Primary Question 1: Does *preemptive*[2] *home delivery* with *free distribution* of ORS and zinc coupled with information about the importance of proper treatment result in greater use of ORS to treat child diarrhea relative to the status quo?

Primary Question 2 (Price Effect): Does preemptive home delivery with *free distribution* of ORS and zinc result in greater use of ORS to treat child diarrhea relative to preemptive home visits with *offers to sell* the products?

Primary Question 3 (Convenience Effect): Does free distribution with *preemptive delivery* of ORS and zinc for household storage result in greater use of ORS than free distribution upon *retrieval* from the CHP's home?

7.1.2 Secondary Research Questions

Secondary Question 1: Among those with free access to ORS, does having ORS stored in the home when a child comes down with diarrhea result in greater ORS use than not having ORS stored at home?

Secondary Question 2: Do *preemptive home visits* with an *offer to sell* ORS and zinc at the typical subsidized price currently charged by CHPs (roughly USD$0.30 per treatment course) coupled with information about the importance of proper treatment result in greater use of ORS to treat child diarrhea relative to the status quo?

Secondary Question 3: Does *free distribution* of ORS and zinc upon *retrieval by caretakers* from the CHP's home coupled with information result in greater use of ORS to treat child diarrhea relative to the status quo?

Secondary Questions 4-6: Same as primary questions but assessed for ORS and zinc combined.

Secondary Questions 7-9: Same as primary questions but assessed for time to ORS use after diarrhea initiation?

[2] "preemptive" implies prior to the occurrence of a diarrhea episode

Secondary Questions 10-11: Same as secondary questions 2-3 but assessed for ORS and zinc combined.

Secondary Question 12: Does having ORS stored in the home when a child comes down with diarrhea result in less time between diarrhea initiation and ORS use than not having ORS stored at home?

Secondary Questions 13-15: Do these interventions reduce antibiotic use?

7.1.3 Tertiary/Exploratory Research Questions

Tertiary Question 1: Does *free distribution* of ORS and zinc upon *retrieval by caretakers* result in greater take-up and use of ORS relative to *preemptive home visits* with an *offer to sell* the products?

Tertiary Questions 2-4: Same as primary questions bus assessed for ORS take-up (probability of obtaining ORS).

Tertiary Questions 5: What is the impact of these interventions on *time between diarrhea initiation and zinc initiation*?

Tertiary Questions 6: Does free delivery of ORS do a worse job of targeting the most vulnerable children (youngest and most severe cases) than imposing hassle costs or prices?

Tertiary Questions 7: Does free delivery of ORS have a larger effect for households with the least access to ORS distributors?

7.2 Empirical Analysis

Since my primary research questions compare Free+Delivery to the control group, the Home Sales group (price effect), and the Voucher group (convenience effect), I will present all results in terms of these comparisons. All analyses were conducted at the child level, which is equivalent to the diarrhea episode level.[3] This is distinct from the household or caretaker level since some caretakers cared for multiple cases of diarrhea.

7.2.1 Outcomes

The primary outcome for the study is self-reported ORS use for a case of child diarrhea that occurred within the last 4 weeks. Since some caretakers cared for multiple children with diarrhea, I restructure data from caretaker surveys to be at the child level. I measured ORS use through a series of survey questions, which asked caretakers who cared for a child with a diarrhea episode in the past 4 weeks whether they used ORS to treat the diarrhea episode. Each case of diarrhea recalled was coded as 1 if the caretaker reported ORS use and 0 otherwise. I used an identical process for creating secondary treatment outcomes; zinc+ORS and antibiotic use. Zinc+ORS was set to 1 if the case was reported as treated with both zinc and ORS. All treatment outcomes were set to missing if 1) the child was not reported to have had diarrhea in the last 4 weeks, or 2) if the caretaker did not know whether the child was given the respective treatment. The full survey and statistical code for creating the main outcomes can be found at the AEA RCT Registry (registry number AEARCTR-0001288).

[3]We only inquired about 1 diarrhea episode per child.

In addition to binary indicators for treatment, I also constructed a variable that indicates the duration between diarrhea initiation and treatment initiation. It is recommended by the WHO that both ORS and zinc are started immediately after the first symptoms of diarrhea. Caretakers that reported providing ORS or zinc were asked how many days passed before they initiated these treatments. This question was used in two ways. First, I created a duration variable that was truncated at 7 days to be used in a duration analysis model (cases that were not treated with ORS were given a value of 7). In addition, I created a variable indicating whether treatment started on the same day as the start of a diarrhea episode (cases that were not treated with ORS were given a value of 0).

7.2.2 Balance Between Groups

First, I compare balance between groups on characteristics that could influence diarrhea treatment patterns. I tested for balance between groups on both exogenous characteristics that should be unaffected by the interventions as well as endogenous characteristics that are likely to be affected by the interventions. For the exogenous characteristics, which include characteristics of the child, caretaker, and household, I tested for balance using data from the endline survey and included only households that had a diarrhea episode in the past 4 weeks (the main analysis sample). Again, this sample is different from the baseline analysis sample, since the survey team visited more households at endline and a different set of children experienced a case of diarrhea. I tested for differences between the control group and the three treatment arms as well as between the Free+Delivery group and other two treatment arms. I used a logit regression to test for differences in binary characteristics and a linear regression to test for differences in continuous characteristics, with standard errors clustered at the village level. Table 1 present results for exogenous characteristics measured in the endline sample. The study team interviewed 7,949 caretakers of children under-5 at endline, of which 2,122 cared for a case of diarrhea in the last 4 weeks. The sample size was fairly well distributed across treatment arms. Randomization appears to have been successful at ensuring balance between groups on characteristics that could affect by ORS use. Caretakers in the Free+Delivery group are slightly older and slightly less educated than the control and Home Sales groups. When I conduct a joint test for orthogonality using a multinomial logit model with treatment assignment as the categorical outcome, I find that the χ^2-test produces a p-value of less than .001. This suggests that these covariates are jointly predictive of group assignment, which is indicative of imbalance and provides some motivation for including these covariates as controls in the main analyses.

For variables that are endogenous to the interventions (diarrhea treatment patterns, knowledge of treatment, access to treatment, and contact with CHP), I used the baseline sample. Although this tests for balance among a different sample than used in our main analysis, the sample of villages remain the same, and this provides a sense of pre-intervention village level balance. The survey team interviewed 4,760 caretakers at baseline 1,537 cared for a case of diarrhea (1,770 cases in total). All variables related to diarrhea treatment or contact with the CHP were only assessed for households with a case of diarrhea. Table 2 demonstrates that groups were balanced at baseline on diarrhea treatment patterns, access to and awareness of ORS and zinc, and visits by the CHP. The Free+Delivery group was less likely to have heard of ORS than the Voucher group, and less likely to have heard of zinc than both the Voucher group and the control group. Since this table examines 60 differences, it is likely that around 3 of these differences will be statistically significant at the 95% level by random chance. I again conducted a joint test for orthogonality on these endogenous covariates measured at baseline and I find that the χ^2-test produces a p-value of .24, suggesting that these covariates are not jointly predictive of treatment assignment.

7.2.3 Evaluation of Intermediate Outcomes

Next, I examined whether the intervention appeared to have been carried out properly and whether variables on the causal pathway were impacted as expected. I expected that all three treatment arms would increase CHP home visits and take-up of ORS/zinc (particularly from the CHP). However, I expected Free+Delivery to increase take-up, to increase home storage of ORS/zinc (implying pre-emptive take-up), and to reduce the likelihood of seeking treatment outside of the home by more than the other two treatment arms, since both price and convenience barriers are addressed (rather than just one of the two).

Table 3 presents means of intermediate outcomes for each group and indicates statistical differences relative to the control and Free+Delivery groups, using a logit model with village clustered standard errors. All of these outcomes include the full sample of households (not just those with a diarrhea episode) aside from indicators for ORS/zinc stored prior to diarrhea episode, visit from CHP, visited CHP's home, and sought treatment outside the home, which only include households with a diarrhea episode. This table provides a picture of what the interventions did and how they could be expected to affect ORS use. The first thing to note is what the status-quo of ORS and zinc take-up looks like, which can be ascertained from the control group (column 1). In the control villages, 25% of households obtained any ORS, only 7.1% obtained ORS from the CHP, and only 4.6% obtained free ORS from the CHP. Only 4% of households received an ORS delivery from the CHP. Only 8% of households received an offer to sell ORS from their CHP at their home. Less than 11% of households had ORS stored at home at the time of the survey or prior to a diarrhea episode. Similar but slightly lower take-up and storage was observed for zinc. Only 24% of control households received a visit from the CHP in the last 4 weeks and 19% visited the CHP's home. Most households that had a diarrhea episode sought treatment outside the home from someone other than a CHP. This description of CHP exposure and treatment seeking patterns in the control villages demonstrates that the intended interventions were indeed an extension of the usual activities performed by the CHP.

The next thing to note is that exposure to the interventions was low. Just over 60% of households in villages assigned to the Free+Delivery group reported a free delivery of ORS. Under 20% of households in the Home Sales group received an offer to sell ORS at the home. Only 42% of households that were assigned to the Voucher group received vouchers. Regardless, assignment to an intervention still substantially increased exposure to the assigned intervention relative to all other groups. Low exposure could occur for several reasons. First, some CHPs did not carry out the intervention as we asked. This is to be expected and would surely also occur if any of these interventions were scaled up. Therefore, CHP non-compliance is part of the effect and provides a more realistic picture of what these interventions would look like at scale-up. Second, it is possible our survey team visited households that were not part of the CHP's catchment area due to inaccuracies on the households list or enumerator error. Third, it possible caretakers simply did not remember receiving the intervention. I expect this last point to be most relevant for the Home Sales group since a visit with an offer to sell ORS and zinc in not out of the ordinary, whereas a delivery of ORS and zinc or a voucher is more salient.

The third thing to note is that there appears to be some spillover of the interventions. Although some free delivery of ORS and zinc is to be expected without the Free+Delivery intervention, there is no reason why free delivery should have *increased* as a result of the Home Sales or

Voucher interventions. It appears that some CHPs assigned to the Home Sales group actually gave their ORS away for free, portrayed by a three-fold increase in free delivery relative to the control group. It also appears that some CHPs assigned to the voucher group delivered their free ORS as opposed to requiring retrieval. Both of these types of spillovers were verified with ex-post qualitative interviews with CHPs. There was minimal spillover of interventions to the control group.

Although exposure was not universal and there was some spillover, I observe the take-up patterns and CHP interactions that would be expected. In the 4 weeks prior to the survey, the Free+Delivery group was much more likely than the control group to obtain any ORS/zinc, obtain free ORS/zinc from the CHP, to have ORS/zinc delivered by the CHP, and to have ORS/zinc stored at home (currently and prior to the diarrhea episode assessed). Vouchers had a directionally similar but smaller effect on these take-up and storage measures. Comparing the Vouchers group to the Free+Delivery group reveals the convenience effect, which is strongly significant for all take-up or storage measures ($p<.01$ for all). This suggests that convenience of access is a barrier to take-up. The Home Sales intervention also increased take-up and storage relative to the control group, but to a much smaller degree than either of the free distribution groups. Comparing Home Sales to Free+Delivery reveals a large and strongly significant price effect ($p<.01$ for all), suggesting that price is an important barrier to ORS and zinc take-up.

Table 3 also shows that the probability of a CHP visit in the prior 4 weeks was higher in all of the treatment groups relative to the control group, but increased by a lesser extent in the Home Sales group than in the other two treatment arms (only 35% of households were visited compared to around 55-60% in the other two groups). Qualitative evidence suggests that CHPs had prior knowledge of which households would be likely to purchase ORS, and chose not to visit households with a low probability of purchase. Since the only difference between groups is that the Home Sales group was instructed to offer to sell products and the other two groups were instructed to deliver products or delivery vouchers, I consider this part of the price effect—free distribution increases home visits relative to charging. However, I also run additional analyses where I control for CHP visit when assessing the price effect (discussed in more detail section 7.5).

Table 3 also shows that Free+Delivery reduced the need for caretakers to seek treatment outside of the home or from a non-CHP provider. This could help avoid the provider barrier discussed in section 5, making ORS and zinc the default treatment option.

7.2.4 Treatment Effects: ORS use

My main analyses are intention-to-treat (ITT), since some CHPs were not trained (due to quitting or unavailability (2 CHPs)), some CHPs did not carry out the intervention properly, and some households did not receive the assigned intervention. By including all CHPs and all households in an ITT analysis, rather than only including households that received the assigned intervention, I preserve the unbiasedness benefits of randomization. However, this will provide a lower bound estimate of the average treatment on the treated (TOT) effect. To complement this ITT analyses and get a better understanding of the average TOT effect of Free+Delivery, I run additional analyses using random assignment as an instrument for receiving the Free+Delivery intervention, which provides a local average treatment effect (LATE)(Imbens and Angrist, 1994). Standard errors are clustered at the village level for all analyses. All analyses were pre-specified with the exception of sections 7.5, 7.6, and 7.7.

I start by presenting means of treatments outcomes by group assignment in Table 4. Differences were assessed using logit regressions with village clustered standard errors. In the control group, 56% of cases were treated with ORS, 20% were treated with ORS on the same day as the diarrhea began, 37% were treated with zinc, 31% were treated with both ORS and zinc, and 26% used antibiotics. All three interventions groups had higher levels of ORS, zinc, and ORS+zinc, with Free+Delivery and Vouchers both exhibiting an increase over Home Sales. Free+Delivery and Vouchers had 76 and 73% ORS coverage, respectively, relative to 66% in the Home Sales group ($p<.01$ for both comparisons). Free+Delivery had significantly higher ORS use on the same day as the start of diarrhea, relative to all other groups (39% compared to 31% in Vouchers, 20% in Home Sales, and 20% in Control). Both Free+Delivery and Vouchers had significantly lower antibiotic use compared to Home Sales and the control group (15-19% compared to 24-26%). These initial results suggest that both Free+Delivery and Vouchers increased use of ORS and zinc relative to both the control group and the Home Sales group. This suggests that price is an important barrier to use. Moreover, the two free distribution groups reduced use of antibiotics relative to the control group. However, there does not appear to be much difference in treatment patterns between the Free+Delivery and Vouchers groups.

Next, I address Primary Research Question 1 more thoroughly. To do so I start by using an unadjusted logistic regression to compare post-intervention differences in ORS use between groups (equation 1).

$$\Pr(ORS_{iv}) = \text{expit}(\beta_0 + \beta_1 FreeDeliv_{iv} + \beta_2 HomeSale_{iv} + \beta_3 Voucher_{iv} + \epsilon_{iv}) \tag{1}$$

Where $FreeDeliv$, $HomeSale$, and $Voucher$ are group assignment indicators, with the control group as the reference category. The β's represent the log odds of the treatment effect of each intervention relative to the control group. I use this equation to estimate the following average marginal effects:[4]

$\mathbb{E}[ORS|FreeDeliv = 1] - \mathbb{E}[ORS|Control = 1]$ (*Primary Question 1*): The impact of the combined effect of free distribution, preemptive home delivery and information.

$\mathbb{E}[ORS|FreeDeliv = 1] - \mathbb{E}[ORS|HomeSale = 1]$ (price-effect, *Primary Question 2*): The effect of preemptive free home-delivery relative to preemptive home sales.

$\mathbb{E}[ORS|FreeDeliv = 1] - \mathbb{E}[ORS|Voucher = 1]$ (convenience effect, *Primary Question 3*): The effect of preemptive free home-delivery relative to free distribution upon retrieval from the CHP's home.

Column 1 of Table 5 presents these estimates and figure 3 presents results graphically. Assignment to the Free+Delivery group resulted in a 20 percentage points increase in the share of cases treated with ORS relative to the control group (76% compared to 56%), which represents a 36% increase ($p<.001$) (Primary Question 1). Assignment to Free+Delivery increased ORS use by 12 percentage points relative to Home Sales ($p<.001$) (Primary Question 2; price effect). There was only a 3 percentage point difference between the Free+Delivery group and the Voucher group and the difference was not significant ($p=.378$) (Primary Question 3; convenience effect).

[4] In practice, I used Stata's margins command.

The estimates above do not account for baseline village-level differences in ORS use between groups (which are small and insignificant but could still affect estimates), nor do they account for potential confounders that are not completely balanced between groups at baseline (Table 2). To account for slight imbalance in baseline ORS use, I include average village level ORS use at baseline as a covariate in equation 1. When autocorrelation in the outcome is low, this is a more efficient way of controlling for baseline outcomes than a difference-in-differences approach (McKenzie, 2012). Since the set of children with a diarrhea episode at endline is different than at baseline, village level autocorrelation in ORS use is likely to be low. I also control for a set of pre-specified caretaker, child, and village level characteristics to account for potential differences between treatment and control groups that could confound the estimates and to improve precision. These include:

Caretaker Characteristics: age, education, number of children
Child characteristics: age, diarrhea frequency per month, blood in stool, concurrent fever
Household Characteristics: water source, latrine type, main source of income
Baseline Village Characteristics: % of households visited by CHP in past month, % of households aware of free ORS in Village, % of households with ORS stored in their home

I also include indicators for each BRAC branch corresponding to each village (6 in total), which functions only to improve precision since randomization was stratified by branch. I estimate equation 2 to adjust for imbalance and to improve precision.

$$\Pr(ORS_{ivbt}) = \text{expit}(\beta_0 + \beta_1 FreeDeliv_{ivb} + \beta_2 HomeSale_{ivb} + \beta_3 Voucher_{ivb} + \beta_4 ORS_{v(t-1)b} + \boldsymbol{X_{ivb}\beta_5} + \lambda_b + \epsilon_{ivbt}) \quad (2)$$

Here, $(ORS_{v(t-1)b})$ represents average village level ORS use in the child's village at baseline, X_{ivb} is a vector of caretaker, child, and village characteristics, and λ_b is a set of branch fixed effects.

Column 2 of Table 5 presents results from equation 2. Adding controls has little effect on the estimates but produces slightly smaller standard errors, implying more precise estimates. Since there was no missing data for any of our control variables, the number of observations remains the same in column 2.

7.2.5 Treatment Effects: ORS+Zinc and Antibiotic Use

To examine the impact of the interventions on secondary treatment outcomes (Secondary Questions 4-6 and 13-15) I estimate equations 1 and 2 with ORS+zinc and antibiotics as the dependent variable. For all secondary treatment outcomes I adjusted p-values using the free step-down re-sampling method to control the False Discovery Rate (FDR) (Anderson, 2008). I included ORS+zinc, antibiotics, and time to ORS use in the family of secondary treatment outcomes. These estimates are presented in Table 6. I find that the impact of Free+Delivery was more extreme for ORS+zinc than for ORS alone (Columns 1 and 2). Free+Delivery of ORS and zinc increased ORS+zinc use by ∼32 percentage points relative to the control group (∼100% increase) and by 21 percentage points relative to home sales a (∼50% increase). Free+Delivery had no effect on ORS+zinc use relative to the Voucher group.

Free+Delivery also led to an 7-8 percentage points reduction (∼30% reduction) in the share of cases treated with antibiotics relative to the control group (Columns 3 and 4). There was no difference in antibiotic use relative to the Home Sales group or the Voucher group.

7.2.6 Treatment Effects: Time to ORS Use

Since ORS was delivered preemptively in the Free+Delivery group, households were more likely to have ORS stored in the home when the child started having diarrhea (See Table 3). I hypothesized that this would lead to a reduction in the time it takes to initiation treatment. To estimate the impact of the interventions on time to ORS initiation after diarrhea initiation (Secondary Questions 10-12) I use two different methods. First I estimate equations 1 and 2 with an indicator for starting ORS on same day as the start of the diarrhea episode as the dependent variable (recommendation by WHO). Columns 1 and 2 of Table 7 present these results. Preemptive Free+Delivery led to a 20 percentage points increase (100% increase) in the probability of ORS initiation on the same day as the start of a diarrhea episode relative to both the control group and the Home Sales group ($p<.001$ for both). Preemptive Free+Delivery also led to a smaller and marginally significant increase in ORS use on the same day as the start of the diarrhea episode relative to the Voucher group (adjusted marginal effect=0.077; $p=.078$).

In addition to a binary assessment of same-day ORS use, I use duration analysis methods with days to ORS use as the duration measure (truncated at 7 days), which provides a more complete picture of the evolution of the group differences over time. Figure 6 presents Kaplan-Meier estimates, which allow for visualization of the group differences over time. Columns 3 and 4 of Table 7 present estimates from a Cox proportional hazard model. I estimate a hazard ratio of 1.6 for Free+Delivery relative to the control group and 1.4 relative to the Home Sales group ($p<.001$ for both). The hazard ratio relative to the Voucher group is greater than 1 but insignificant ($p=0.179$).

7.2.7 Local Average Treatment Effect of Free+Delivery

As I mentioned above, not all households in villages assigned to the Free+Delivery group actually received a free delivery of ORS and zinc. Therefore, our estimates from tables 5-7 are under-estimates of the treatment on the treated effect. To get a better understanding of the impact of actually receiving a free delivery relative to the control group, I use random assignment as an instrument in a two-stage least squares framework. Formally, I estimate the following system of equations including only the control group and the Free+Delivery group.[5]

First Stage:

$$FreeDelReceived_{ivt} = \beta_0 + \beta_1 FreeDelAssigned_{iv} + u_{ivt} \tag{3}$$

Second Stage:

$$ORS_{ivt} = \alpha_0 + \alpha_1 FreeDelReceived_{iv} + \epsilon_{ivt} \tag{4}$$

The key assumption that has to hold for random assignment to be a valid instrument in the above framework is that assignment to the Free+Delivery group only affects ORS use

[5] Equations 3 and 4 were not pre-specified

through increasing the probability of a free delivery of ORS (i.e. $FreeDelAssigned \perp \epsilon$). Increased supply of ORS to the CHP in Free+Delivery villages could lead to a violation of this assumption. To test for the impact of supply, I compare ORS use between the control group and the Home Sales group but only include households that did not receive a CHP home visit. Since all households included in this analysis did not received a visit from the CHP, the main difference between these groups is increased CHP supply of ORS in the Home Sales group. I find no difference in ORS use between these groups (difference of .02 percentage points, p=.6), suggesting that increased supply alone had little effect on use.[6] Another assumption is that receiving a Free Delivery is not differentially over-reported among ORS users relative to non-users. If caretakers that received a free ORS delivery but did not use it, lied about receiving the delivery, this would overestimate the effect of free delivery. However, reports of free delivery was partly used to identify which households receive a payment for observing the remaining packets. Only 6 households that did not use ORS and did not report a free delivery had any packets available to show. It is unlikely that a large portion on households forwent the payment to validate their lie.

I estimate that free delivery leads to a 37 percentage point increase in ORS use relative to the control group (no change when controls are added)(Table 8). This is a LATE, and implies that among households that would receive a free delivery of ORS if their CHP was instructed to carry out the Free+Delivery intervention, ORS use would increase by 37 percentage points.

7.2.8 Local Average Treatment Effect of Home Storage

A more fundamental question is whether having ORS and zinc stored in the household pre-emptively (i.e. prior to a diarrhea episode) results in higher ORS use than having to go retrieve the product once a diarrhea episode begins. If this is the case, then other interventions beyond CHP delivery could be used to increase home storage rates. For example, public health facilities could give ORS away preemptively during post-natal check-ups or larger quantities of ORS could be provided for diarrhea cases to be stored for future use. In order to answer this question, I again use random group assignment as an instrument, but in this case as an instrument for preemptive home storage. For this analysis I only use participants in the Free+Delivery and Vouchers groups. Free distribution is held constant between these groups, with the only difference between groups being that Free+Delivery households had products delivered prior to a diarrhea episode whereas the Voucher group had to retrieve the product. I expected that pre-emptive home delivery would increase pre-emptive home storage relative vouchers. I use the same framework described above in equations 3 and 4. Table 9 presents these results. The first stage (columns 1 and 3) shows that assignment to the Free+Delivery group increased the probability of home ORS storage prior to a diarrhea episode by about 18 percentage points. However, the first stage of the unadjusted model has an F-statistic below the rule of thumb threshold of 10, suggesting a somewhat weak first stage. When controls are added, the F-statistics on the excluded instrument in 12.4, indicative of a strong first stage. The second stage (columns 2 and 4) demonstrates that this increase in home storage of ORS did not lead to a statistically significant increase in ORS use although the coefficient was large in magnitude (marginal effect=.175; p=.296). This suggests that we are underpowered for this analysis and cannot rule out large effects of Home Storage on ORS use. However, I do find that home storage led to a statistically significant increase in ORS use on the same day as the

[6] Home visits are not randomly assigned and CHPs could select to visit households that are more likely to use ORS, which would imply that the estimated effect of supply is biased downward. Therefore, this result should be interpreted with caution.

start of a diarrhea episode (44 percentage points; p=.042; see Table 10).[7]

7.2.9 Heterogeneous Treatment Effects

For targeting purposes, it might be helpful to understand for what types of villages or households these interventions will be most effective. I assess how the program affects outcomes differently based on several pre-specified characteristics.

Heterogeneity by ORS Access
Free+Delivery might be particularly effective for areas that are farther away from ORS and zinc distributors. To test this, I measure how each treatment arm affects outcomes differently for villages that are farther away from distributors (Tertiary Question 12). I measure distance as the time (in 10 minute increments) it takes to travel to the nearest ORS distributor as reported in the household survey (not including the CHP as a distributor).

In order to assess heterogeneous treatment effects by distance, I created interaction terms that interact distance (time it takes to arrive at the nearest ORS distributor) with each treatment group indicator. I then estimate the following equation.

$$\begin{aligned} ORS_{ivt} = \beta_0 + \beta_1 FreeDel_{iv} + \beta_2 HomeSale_{iv} + \beta_3 Voucher_{iv} + \beta_4 Dist_v + \\ \beta_5 DistXFreeDel_{iv} + \beta_6 DistXHomeSale_{iv} + \beta_7 DistXVoucher_{iv} + \epsilon_{ivt} \end{aligned} \quad (5)$$

Equation 5 tests how treatment effects vary by time to reach the nearest ORS distributor. A positive and significant coefficient on the interaction terms (β_5-β_7) would suggest that people with less access to ORS distributors (further away) experienced a larger improvement relative to the control group. I find no evidence that the impact of Free+Delivery (or either of the other interventions) was more pronounced for households that were further away from an ORS distributor (Table 11). These results are highlighted in Figure 7, which demonstrates that there was very little difference in the effect of Free+Delivery on ORS use relative to the control group at different distances from a distributor. However, it is important to note that this study was not designed to measure heterogeneity and confidence intervals are very wide. Moreover, most households were reasonably close to the nearest distributor (median of 5 minutes) and there was not much variation in distance. The effect of Free+Delivery may indeed be larger for households that are required to travel longer distances, but we have insufficient sample of these types of households identify such an effect.

Heterogeneity by Child Vulnerability
It is also important to understand how each of our interventions affect ORS use for the most vulnerable children (Tertiary Question 11). For example, does free delivery expand coverage to less vulnerable children or children that are not likely to die from diarrhea? Does charging for ORS or requiring small hassle costs do a better job of targeting resources to the most vulnerable than giving ORS away for free? To assess these questions, I test for heterogeneity in intervention impacts by two different measures of child vulnerability.

1. **Age:** The majority of deaths from diarrhea happen within the first year of life. I used a dummy variable indicating that the child is less than 12 months old.

[7] Analysis not pre-specified

2. **Severity of Episode:** I used two criteria to identify severe episodes: concurrent fever and blood in the stool. I coded a case as "severe" if either of these criteria are satisfied.

I tested for how ORS use is affected differently based on these characteristics using the same interaction model framework outlined in equation 5 (estimates presented in Table 11). I find no evidence that Free+Delivery expands coverage more for older children. The coefficient on the interaction term is positive and significant, suggesting that Free+Delivery expands coverage by *more* for children less than 1-year old relative to the control group. I also find no difference in the effect of Free+Delivery by age relative to the Home Sales or Voucher groups.

I also find no evidence that the effect of Free+Delivery leads to expanded coverage for less severe episodes, relative to any of the other groups. However, I estimate a negative coefficient on the interaction term between severity and Free+Delivery (relative to the control group), which is large in magnitude (10 percentage points) but statistically insignificant (p=.140). Therefore, I can't rule out that Free+Delivery expands access to less severe cases in an important way.

Heterogeneity by Baseline ORS use (not pre-specified)
Finally, I also assessed heterogeneity in treatment effects by baseline ORS use. The villages enrolled in this study had above average ORS use at baseline compared to national statistics (over 60% compared to the 46% national average). This analysis helps provide insight into what the impact of the interventions would look like if scaled up to villages with lower levels of ORS use. Figure 8 presents a lowess smoothed curve of the relationship between baseline ORS use and endline ORS use. This figure demonstrates two things. First, baseline ORS use is a strong predictor of endline ORS use in the control group but has no predictive power for ORS use in the Free+Delivery group. Second, much of the effect is driven by sizable increases in ORS use among villages that started off particularly low. Figure 9 presents treatment effect estimates by quartile of baseline ORS use. The effect was strongest for the first quartile (34 percentage points increase) and smallest for the fourth quartile (9 percentage point increase), again demonstrating the effects are driven by villages that started off with low ORS use. Interaction models show that the treatment effect is statistically different between the 1st and 4th quartiles (interaction term=.249; p=.018) and between the 3rd and 4th quartiles (interaction term=.156; p=.079). I find similar results for the Voucher and Home Sales interventions (available upon request).

7.3 Addressing Problems With Self-Reported Outcomes

My main outcome measures are self-reported, which creates several concerns about measurement error. First, there is potential for social desirability bias where caretakers intentionally over-report ORS use. Second, there is potential for recall bias where caretakers mis-remember their past treatment behavior. If either type of measurement error in outcomes is correlated with treatment assignment, this would compromise the study's internal validity. I conducted several test to help validate self-reported outcomes, which I outline below.

7.3.1 Intentional Over Reporting of ORS Use

It is possible that there is differential intentional over-reporting of ORS use in the treatment and control groups. For example, caretakers that received free ORS might over-report use with the hope of receiving more free ORS in the future or in an attempt to appease the interviewers. All treatment groups might over report ORS use relative to the control group since the CHP told them they were supposed to use it. I address this potentially differential over-reporting in several ways.

Counting Packets
In the Free+Delivery group, CHPs instructed caretakers to keep the ORS and zinc packets that were delivered (used and/or unused), and that if packets were available for our survey team to observe, they would be provided a small incentive (about $0.30 (USD)). It was not feasible to incentivize packet retention in the other three groups, as that would have incentivized acquisition of ORS. During the endline survey, enumerators recorded 1) if any packets were observed, 2) the number of used packets, and 3) the number of unused packets. Of the 518 diarrhea cases from households visited in the Free+Delivery villages[8], 59% retained at least some of the ORS/zinc packaging. However, as I mentioned above, not all households received a free delivery. Of those that reported receiving a free delivery, 80% had some the packaging left. I use the results from counting these ORS packets to create several alternative measures of ORS use that are less reliant on self-report. I use two different metrics based on observed packets to identify ORS use: 1) at least 1 empty packet observed (implying that the contents of the packet was used), and 2) fewer packets observed than obtained in the last 4 weeks.[9] I also restricted the sample in two ways to help refine the measure. First, I included only cases that received a delivery, since only households the received a delivery would be expected to have any packets to observe. Second, I included only cases where caretakers had at least 1 packet to show the enumerator. I also restricted to caretakers that had both of these criteria satisfied.

Results for 8 different alternative measures are presented in Table 13. I present the average estimate for each sample using both the counting measures (empty packets or observed<obtained) and self-report measure. I also present estimates stratified by self-reported ORS use, which provides insight into how frequently the counting and self-reported measures are in agreement. The first thing to note is that very few caretakers had empty packets (top panel). Row 1 shows that only 34% of cases were in households that had at least one empty packet (42% of self-reported ORS users), whereas 77% of these caretakers reported using ORS. This either means that many caretakers used ORS and did not save the empty packets or they were over-reporting ORS use. Restricting the sample to those that received a delivery (row 2) improves consistency with self report, however still only 47% saved at least one empty packet (51% of self-reported ORS users). Restricting the sample further increases the likelihood of an empty packet, however agreement with the self-reported ORS users never exceeds 65% and the average measure never exceeds 58% of cases treated, substantially lower than the self-reported measure.

Many caretakers reported disposing of empty packaging, which could explain the discrepancy between observed empty packets and reported use. To account for this, I created a more flexible measure, where a case is coded as treated with ORS if the household had fewer full ORS packets than they reported acquiring in the last 4 weeks. Row 1 of panel 2 presents this measure for the full sample. Overall, I find that 75% of caretakers had fewer full ORS packets than they reported obtaining (panel 2, row 1). Moreover, among those that reported using ORS, 92% had fewer packets to show than they reported obtaining, suggesting strong agreement with the self-reported measure. Further restricting the sample improves agreement with the self-reported measure and increases the estimated share of cases treated using the counting measure. The final row of (Table 13) recodes the households that reported no ORS to zero (i.e. assumes that no one under-reports ORS use), which lowers the estimated share of cases treated to 83% (column 3).

These results suggest that there was likely only a small degree of over reporting, however most households that reported ORS use had fewer packets to show than they reported obtaining.

[8]Number excludes villages where no CHP carried out the intervention (40 cases)
[9]number of packets obtained was recored in an earlier survey question unrelated to counting observed packets

Caretakers would have had to plan out their miss-reporting in a sophisticated way to report obtaining more packets than they had available to show. Since households were paid to show their packets, it is unlikely that they would withhold packets and forgo the incentive.

Since households that received a free delivery are most likely to have received the intervention and been instructed to save their packets, I consider measures using this sample the most accurate way of validating self reported measure. Using the recoded measure in the final row of Table 13, I find that 6% of ORS users were not accurately reporting ORS use. To identify a lower bound of the effect of Free+Delivery void of differential over-reporting, I assume that over-reporting only occurred among households in the Free+Delivery group that received a free delivery (there is no reason to expect that there would be differential over-reporting for households that did not receive the intervention and those households have similar rates of ORS use to the control group at 58%). I reduce the share of cases treated with ORS for the 60% of households in the Free+Delivery group that received a free delivery by 6%. After applying this 6% reduction and taking the weighted average of those that did and did not receive a free delivery, adjusted ORS use in the Free+Delivery group becomes 73.4%. This is still an 18 percentage point increase over the control group and 9 percentage point increase over the Home Sales group. Therefore, even if I assume that over-reporting only occurs in the Free+Delivery group, there is still a substantial increase in ORS use as a result of the intervention. I have to assume an over-reporting rate of 40% that only occurs in the Free+Delivery group for free delivery households to get to the control group ORS usage level. This analysis provides confidence that there was not a large of amount of over-reporting and that even if there were some degree of differential over-reporting, the true effect is still a substantial improvement in ORS coverage.

Placebo Tests
Next, I conducted a series of placebo tests to examine differences between treatment groups on self reported child health behaviors that should not be affected by the interventions (negative controls or placebo outcomes). We should expect no treatment effect on self-reported outcomes that are not affected by the interventions. I tested for placebo treatment effects on the four pre-specified binary outcomes outlined below, all of which are part of the CHP's normal activities.

1. Caretaker gave child malaria treatment (conditional on symptoms)
2. Caretaker gave child food or liquid that was unclean
3. Child always slept under a bed net
4. Child washed hands at least twice per day

I used the same methodology described in section 7.2.4 to measure placebo effects. Table 14 demonstrates that there was no difference between Free+Delivery and any of the other groups on any placebo outcomes. This provides confidence that caretakers were not broadly over-reporting healthy behaviors addressed by the CHP program in the intervention groups.

7.3.2 Unintentional Misreporting Of ORS Use: Shorter Recall

Since our main outcome asks respondents to recall diarrhea episodes and treatment behavior that occurred in the past 4 weeks, some respondents may have had trouble accurately recalling how episodes were cared for. We chose this recall period to aligned with the period when the intervention was active and to satisfy our sample size criteria. However, it is possible that this recall duration was too long to produce valid estimates. Moreover, this measurement error from recall could be correlated with treatment assignment. For example, free delivery households might be better at remembering ORS use accurately since the delivery made ORS use more salient. To address this, I restrict the analysis to 1) diarrhea cases that are ongoing during endline data collection (about one third of reported diarrhea cases), and 2) diarrhea cases that ended within 7 days of data collection (about 68% of cases), which is the optimal time frame for diarrhea recall documented by Arnold et al. (2013). Results for these different recall periods are presented in Table 15. Point estimates for 7-day recall are nearly identical to the main results in Table 5. Relative to the control group, point estimates for current episodes are smaller in magnitude, but similar in terms percent change. However, the effect of Free+Delivery relative to Home Sales is attenuated and insignificant for current episodes. Overall, these results suggest that differential recall bias is not driving the treatment effect estimates I reported in Table 5.

7.4 Attrition and Changes in Group Composition

7.4.1 CHP Attrition

In order for CHPs to carry out their randomly assigned intervention, they must receive a training session that instructs them on the required tasks and provides them with enough ORS and zinc for all children under-5 in their village. In two villages, the CHP was randomly assigned to the Free+Delivery group but did not actually receive training on how to carry out the intervention or receive the ORS and zinc to distribute. In one village, a CHP was assigned to the control group, but then quit prior to the endline survey. This type of CHP attrition could change group composition and result in groups no longer being exchangeable. Our ITT analysis includes all villages, regardless of whether the CHP was trained or present in the village, to preserve the benefits of randomization. When I restrict the analysis to only CHPs that were trained and still present in the village (excluded 40 cases), results are unchanged (available upon request).

7.4.2 Differential Household Refusal

One concern is that more households in villages where something was given away for free (Free+Delivery and Vouchers) will agree to be surveyed at endline than in the groups where no gifts were given out. If these additional households in the free distribution groups are systematically more or less likely to use ORS, this could compromise the study's internal validity, since groups would no longer be comparable. However, refusal to participate was very rare (less than 1%) so differential refusal is not a concern.

7.4.3 Differential Reporting of Diarrhea Episodes

Another more concerning channel through which group comparability could be compromised is through differential reporting of diarrhea episodes. Since the main outcome of interest (ORS use) is contingent on a child having had a recent case of diarrhea, we only have outcome information for children that had a recent diarrhea episode. If caretakers in a treatment group are more or less likely to report a diarrhea episode, this could bias our results. Table 1 shows that households in the treatment groups were all about 3 percentage points less likely to report a diarrhea episode (not statistically significant). To bound the potential bias that this produces for the Free+Delivery group, I assume that prevalence in the Free+Delivery group was identical to that in the control group, adding about 71 cases to the Free+Delivery group. If I assume that all of these cases did not use ORS, ORS use in the Free+Delivery group reduces to 69%, still a 13 percentage points increase over the control group (p<.01). This suggests that differences in sample composition due to potentially differential reporting of a diarrhea episodes cannot fully explain the increase in ORS use produced by Free+Delivery. Results available upon request.

7.5 Isolating the Demand Side Price-Effect

My intervention arms were designed to isolate for the role of price and convenience in ORS use. CHP trainings only differed on whether they were instructed to charge, deliver for free, or provide vouchers to households. All other aspects of the trainings were held constant across intervention group. Therefore, my ITT analysis provides an estimate of the price and convenience effect at the CHP program level, which encompasses both supply side and demand side effects. This addresses questions such as "What is the impact of a program design where CHPs are told to delivery ORS for free relative to a program design where CHPs are told to charge for ORS?". However, another important question is "how sensitive are households to the price of ORS, and how much does the offer price affect use?" Supply side effects occur when CHPs change the quantity of ORS supplied or the effort used to supply the ORS to households, as a result of the intervention. Demand side effects occur when households change the quantity of ORS obtained as a result of the intervention. Since the interventions simultaneously had both supply side effects (e.g. change in CHP effort) and demand side effects (e.g. change in the price faced by the household), isolating the demand side price effect is challenging.

7.5.1 Differential CHP effort

The most glaring differential supply-side effect is that households in the Home Sales group were much less likely to have received a visit from the CHP than the other two treatment arms (35% vs. 60%; See Table 3). This was a surprising result since CHPs in the Home Sales group had an extra financial incentive to visit households, as they were allowed to keep the revenue from any sales, which were offered at the market price. Qualitative evidence revealed that many CHPs did not expect households to purchase the ORS and zinc and therefore avoided completing all household visits. Several CHPs reported that they would have visited more households had they been providing ORS for free. This is an interesting result, and implies that the incentive of providing a household with free ORS increases CHP effort by more than the incentive of potentially receiving the revenue from a sale. This is consistent with prior work demonstrating that the type of person who becomes a CHP is more intrinsically or socially motivated (Deserranno, 2014) and evidence that social incentives can be more powerful than financial incentives (Ashraf et al., 2014). However, as a result, the difference in ORS use between Free+Delivery and Home Sales includes both the demand side price effect (the price the household faces) and the effect of receiving additional CHP visits. To isolate the demand side price effect, I conduct an additional analysis where I control for an indicator variable set to 1 if the CHP visited the household in the last 4 weeks (not pre-specified). These results are presented in Table 16. Columns 1 and 3 repeat the primary analysis from Table 5 for comparison, and columns 2, 4, 5, and 6 control for CHP visit. Receiving a CHP visit was an important predictor of ORS use (25 percentage point increase, p<.01). After controlling for CHP visit, the estimated price effect reduces by roughly 50%, but is still statistically significant at the 95% level (marginal effect=.063; p=.049). Adding controls decreases the estimate slightly (marginal effect=.055; p=.045).

Controlling for a post-treatment indicator for CHP visit, as I do in Table 16, is an imperfect way of holding CHP effort constant, since it assumes the probability of a CHP visit is orthogonal to ORS use (Acharya et al., 2016). In reality, CHPs selected which households to visit. Both economic theory and qualitative evidence suggests that CHPs in the Home Sales group selected households that were more likely to purchase and use ORS. Qualitative interviews with CHPs in the Home Sales group revealed that they avoided poorer households, households that were historically less receptive to BRAC programs, and those whom they expected held lower regard for ORS and zinc. Therefore, expanding Home Sales visits to the remaining households would likely have a diminishing effect on ORS use, and the demand side price-effect I estimated in this section is likely a lower bound. Table 17 presents caretaker, child, and household characteristics by whether the household received a CHP visit (Free+Delivery and Home Sales groups only). This table provides some support for the assumption that CHPs selected households that were more likely to use ORS. For both Free+Delivery and Home Sales villages, CHPs visited households with older caretakers, more children under-5, older children, and a primary income coming from agriculture. All of these characteristics are positively correlated with ORS use in the control group (see Appendix Table A5). Moreover, a joint test for orthogonality produces a χ^2-test with $p < .01$, suggesting that CHP visits are non-random.[10] If CHPs indeed visited households that were more likely to use ORS in absence of the intervention, controlling for CHP visit produces a lower bound of the demand side price-effect. However, even this lower bound estimate is significant and of important magnitude.

7.5.2 Free distribution in the Home Sales group

Another issue that hinders estimation of the demand side price effect is that many CHPs in the Home Sales group gave ORS away for free (see table 3). 33% of households that received a CHP home visit in the Home Sales group received free ORS from the CHP. In order to further isolate the demand side price effect, I exclude households in the Home Sales group that received free ORS from the CHP. Columns 5 and 6 of Table 16 presents these results. Exclusion of these households leads to demand side price effect of 7-8 percentage points (p<.01). However, the choice to give away ORS for free in the Home Sales group is also not random, and therefore excluding this non-random sub-group could produce unpredictable bias. Therefore, these results should be interpreted with caution.

7.6 Knowledge of ORS and Zinc Use

7.6.1 Impact on Knowledge

Although awareness of ORS is rather high in Uganda (over 95% of caretakers had heard of ORS at baseline), inaccurate knowledge of the importance/effectiveness of ORS could lead to under-use. Awareness of zinc is lower (roughly 70% at baseline), suggesting there is room for increasing zinc use simply by spreading awareness. The team instructed CHPs to provide the standard information on ORS and zinc use (see Figure A1) during household visits, and knowledge of ORS and zinc could have improved as a result. I test for the impact of the treatments on ORS and zinc knowledge using several different measures of knowledge: reported ORS/zinc as best treatment for child diarrhea; reported that should start ORS/zinc after first loose stool;

[10] This test was done separately within Free+Delivery and Home Sales households. I used a logit model with CHP visit as the outcome and the characteristics from Table 17 as explanatory variables

reported accurate frequency of ORS/zinc use; reported accurate duration of zinc use. Table 18 presents estimates of these interventions on knowledge measures. There were sizable effects on caretakers reporting that ORS, zinc, and ORS+zinc were the best treatments for diarrhea, and the largest improvements occurred for zinc related outcomes. Knowledge of proper ORS use also increased (initiation and frequency). There was no effect on appropriate knowledge of zinc frequency or duration. These results suggest that the increase in CHP visits produced by the interventions led to improvements in knowledge of the importance of ORS and zinc use as well as how to use the treatments appropriately.

7.6.2 Knowledge as a Mechanism

It is possible the improvements in knowledge described above were driving the treatments effects from Table 5. To address this, I run an additional analysis where I control for knowledge that ORS is the best treatment for child diarrhea in equations 1 and 2 (Table 19). After controlling for this knowledge metric, the Impact of Free+Delivery relative to the control group and the Home Sales group reduces by about 25-35%. When I use the Baron and Kenny procedure for mediation analysis allowing for interactions between treatment assignment and the mediator, I find similar results (not presented) (Baron and Kenny, 1986). This suggests that improvements in knowledge were indeed a mechanism through which the interventions worked, however, a large share of the effects were the result of other mechanisms (e.g. differences in price). However, these estimates should be taken with caution for several reasons. First, CHPs had to visit the households to provide education, therefore the knowledge indicator captures part of the effect of CHP visit selection. This will attenuate the impact of Free+Delivery for the reasons described above for CHP effort. Second, since reporting that ORS is the best treatment is not randomly assigned, it is likely that the additional caretakers reporting ORS as the best treatment in the Free+Delivery group had a lower underlying propensity to use ORS than those reporting the same in the control and Home Sales groups. This is because caretakers reporting ORS as the best treatment without intervention likely had a higher baseline propensity to use ORS. This would also attenuate effect of Free+Delivery. Finally, reports that ORS is the best treatment are likely endogenous to ORS use. In others words, people that used ORS as a result of the Free+Delivery intervention might be more likely to report ORS as the best treatment for child diarrhea precisely because they used it recently (and liked it). This too would attenuate the effect of Free+Delivery. For all of these reasons, controlling for knowledge likely produces a lower bound of the impact of Free+Delivery void of the knowledge effect.

7.7 Examining Mechanisms

In order to identify which mechanism are at work for each of the three interventions, I sequentially add post-treatment intermediate outcomes (mechanisms) to equation 1. Adding these controls is an imperfect way of identifying the role of mechanisms and therefore this analysis should be interpreted with caution (Acharya et al., 2016). Moreover, this analysis was not pre-specified. Appendix Table A2 examines the mechanisms at work in the Free+Delivery group (relative to the control group). Column 1 presents the unadjusted estimates from Table 5, and Column 2 controls for a variable indicating whether the caretaker obtained ORS from the CHP. When I included this control, the effect of assignment to Free+Delivery completely disappears, suggesting that nearly all of the effect is coming from increased ORS distribution by the CHP. Columns 3, 4, and 5 iteratively add less broad controls (visit from CHP, free delivery from CHP, and storage of ORS prior to diarrhea). Controlling for visit from CHP (column 3) reduces the estimate from column 1 by about 40%, which is still statistically significant (marginal effect=.124, p<.01). Column 4 adds an indicator for receiving a free delivery of ORS (i.e. exposure to the intervention), upon which the effect becomes small and insignificant. Controlling for home ORS storage in column 5 further reduces the magnitude of the effect to almost zero. This demonstrates that the main mechanisms through which we expected the intervention to impact ORS use (see section 4) are able to explain away the effect of assignment to Free+Delivery. This provides some confidence that this intervention was working through the expected channels.

See Tables A3 and A4 for a similar exercise for the Voucher and Home Sales groups , respectively (relative to the control group).

7.8 Summary of Treatment Effects

This section documents substantial increases in ORS and ORS+zinc use as a result of a CHP program that distributes ORS and zinc for free relative to a CHP program that charges. Both instructing CHPs to delivery ORS and zinc for free and instructing them to provide vouchers for free retrieval led to increases in ORS and zinc use relative to instructing door-to-door sales. Estimates of the LATE show that actually receiving the Free+Delivery intervention increased ORS use by 37 percentage points. This implies that BRAC and other CHW programs could increase coverage of ORS+zinc by having CHWs distribute products for free rather than charging. These results are robust to different recall periods and self report measures were mostly validated by counting packets.

Free+Delivery increased ORS use relative to Home Sales suggesting a price effect at the CHP program level (including supply and demand side effects). Instructions to charge for products at the program level substantially reduced the probably of making household visits, and it appears the program level price effect embodies both the effect a households receiving additional CHP visits and receiving a free ORS delivery. After controlling for CHP visit to further the demand-side price-effect, I still find a (lower bound) price-effect of 5-9 percentage points, about half the size of the effect at the program level. These results suggest that price is a barrier to ORS use, both from the supply side and the demand side. I find no evidence of a convenience effect. This suggests that when the hassle cost is small (most households only had to walk about 10 minutes to a CHP's home), such a cost is not a barrier to ORS and zinc use.

I don't find strong evidence that the coverage gains from Free+Deliver or Vouchers is driven by expanded distribution to less vulnerable cases. Neither intervention had a stronger effect for older children, and results point in the opposite direction. However, point estimates suggest that there may have been weaker effects of an important magnitude for more severe cases, suggesting expanded coverage to less severe cases. However, this result was not statistically significant.

The Home Sales group portrayed only a small improvement over the control group. This is an important result since the home sales intervention in essence improves the functionality of the current CHP model. In other words, it provides a picture of what ORS use looks like when the CHP program is working closer to what is intended (CHPs are stocked with ORS+zinc, make monthly households visits, provide information to caretakers, etc.). The Home Sales intervention ensured that CHPs received large quantities of ORS and zinc, and increased the probability that CHPs visited households, provided information, and offered to sell ORS and zinc. This can be thought of as an upper bound of the potential for ORS coverage under the current CHP model. This result highlights that improvements to the functionality of the status quo can only achieve about one third of the increase in coverage gains observed in the free distribution groups.

There was an improvement in knowledge of ORS and zinc as a result of the interventions and these improvements may have been a channel though which the interventions worked. However, after controlling for knowledge, I still find large treatments effects, which are likely a lower bound due the endogeneity concerns.

7.9 Limitations

There are several limitations of the analysis of treatment effects that could limit internal validity and make interpretation of the results complex. The most glaring limitation is reliance on caretaker reports for our main outcome (ORS use). Caretaker reports are used to monitor ORS use globally and are the key metric used to influence decision making around treatment of child diarrhea. However, it is unclear if such reports are accurate. I demonstrate that comparing counts of full packets observed to reports of total packets acquired produces similar ORS coverage estimates as caretaker reports. However, I was only able to count packets in the Free+Delivery group, and this measure still relies on self-reports of ORS acquisition. Future studies should identify a more robust way of measuring ORS use at the household level.

Second, this study only identifies the short term impact of these interventions. It is unclear what the Free+Delivery intervention would look like at scale-up or if CHPs would continue to make the deliveries over time. It is also unclear if hassle cost would be more of a barrier over time. Providing households with vouchers could have increased the salience of ORS take-up, leading to increased demand or willingness to endure the hassle of retrieval in the short term. Over time, the salience effect could diminish and free distribution with retrieval could be less effective, particularly if vouchers are not delivered. Free and preemptive delivery would achieve continued salience since deliveries would recur.

Third, our sample is not representative of the rest of Uganda. All villages had a CHP present in the village at baseline, which could explain above average baseline ORS use (60% compared to a 46% country average). Moreover, most village were peri-urban, whereas much of Uganda is rural. Therefore, it is unclear what these effects would look like if scaled up nationwide. However, I do find that the effect of Free+Delivery is larger for households in villages with lower baseline ORS, which are more representative of the rest of Uganda. Therefore, it seems plausible to expect that the effect of Free+Delivery would be at least as large in the short term if scaled-up to other Ugandan villages.

8 Free-Distribution, Hassle Costs, and Targeting to Compliers

8.1 Background on Targeting to Compliers

Ideally, a policy maker would like to use subsidies to maximize coverage of health products while minimizing wastage of these subsidized products. This is achieved by giving products to people with a high propensity for use (compliers). Free distribution vs. cost sharing for health products has been a contentious issue in terms of targeting scarce subsidies to compliers. Proponents of charging for health products argue that people don't value products that are given away for free

(PSI, 2003). Charging for products could increase use through the *sunk cost effect* (Thaler, 1980) and improve targeting and reduce wastage through the *selection* or *screening* effect (Ashraf et al., 2010; Cohen and Dupas, 2010). If such effects are present, charging for health products could help avoid product wastage. However, public health proponents often argue that charging for health products will reduce coverage by dampening demand, particularly among the poor and vulnerable. The experimental design of this study allows me to assess the trade-offs in ORS coverage and targeting ORS to compliers (caretakers that will use ORS if available), and how those trade-offs differ between Free+Delivery, Voucher, and Home Sales groups. Although take-up and coverage of ORS is highest in the Free+Delivery group, it is possible that a portion of the free ORS was delivered to caretakers that were never going to use it, resulting in wastage. Requiring that caretakers pay for ORS or retrieve it from the CHP's home could do a better job screening out non-compliers.

Several studies have assessed these trade-offs for other health products. Cohen and Dupas (2010) found no evidence of the sunk cost effect or the screening effect when comparing free distribution and cost-sharing for bed nets in Kenya—pregnant women who got free nets were no less likely to use them than women who paid for the nets. However, even highly subsidized prices dramatically reduced coverage of bed nets relative to free distribution. This suggests that free distribution increased coverage without reducing compliance or increasing wastage. Ashraf et al. (2010) also found no evidence of the sunk cost effect for point-of-use water treatment in Zambia, however they did find evidence of the screening effect—households that had a higher propensity to use the product were willing to pay a higher price. This suggests that increasing prices could indeed reduce wastage, but at the expense of reducing coverage. Using a similar experimental design as the present study, Dupas et al. (2016) revisit prices, take-up, and wastage of point-of-use water treatment in Kenya by comparing subsidized prices, free distribution upon retrieval, and free delivery. They found that the hassle cost of retrieving the free product vs. having it freely delivered reduced take-up by 15% but with no reduction in product use. On the other hand, a discounted but positive price reduced take-up by 48% but also reduced use by 62% relative to free delivery. This suggests that imposing hassle costs could be a more efficient way of targeting products than either free delivery or charging, since it produces less wastage than free delivery without sacrificing coverage.

8.2 Conceptual Framework

Let α_i be the share of respondents with a diarrhea episode in intervention i that acquired subsidized ORS from the CHP during the study period (take-up) and μ_i be the share of respondents that used ORS to treat a case of diarrhea during our study period (coverage). Let λ_i, be the share of those that obtained ORS that used it to treat a case of diarrhea (roughly $\frac{\mu_i}{\alpha_i}$)[11] (compliance). There are three important inequalities of interest between the $\lambda's$ and $\mu's$:

1. $\lambda_i > \lambda_j$ and $\mu_i < \mu_j$: this implies that intervention i does a better job of targeting to compliers than intervention j, but intervention j does a better job of getting ORS to all that need it.

2. $\lambda_i > \lambda_j$ and $\mu_i \geq \mu_j$: this implies that intervention i does a better job of targeting to compliers than intervention j, and also does at least as good of a job at getting ORS to all that need it.

3. $\lambda_i \geq \lambda_j$ and $\mu_i > \mu_j$: this implies that intervention i does at least as good as good of a job of targeting to compliers as intervention j, but does a better job at getting ORS to

[11] Due to measurement errors, this ratio is not exact

all that need it.

Prior evidence discussed above suggests that hassle costs do a better job of targeting to compliers and at least as good of a job of getting ORS to all that need it relative to free distribution (scenario 2). Prior work also suggests that charging sacrifices coverage but improves targeting to compliers (scenario 1).

8.3 Methodology and Results

In order to assess trade-offs in coverage and targeting to compliers, I use estimates of coverage (documented in section 7.2.4), take-up (total and from the CHP), and the probability of use conditional on take up (compliance). I define take-up as acquiring ORS in the last 4 weeks. To estimate compliance, I estimate the share of caretakers that obtained ORS in the last 4 weeks that used ORS to treat a case of diarrhea. I estimate these measures for the entire sample of households and for the sample of households that reported a case of diarrhea. The former is important since households without a diarrhea episode are likely to take-up ORS under free distribution, which could lead to wastage. However, it is unclear if ORS that goes unused due to lack of diarrhea episode will get used in the future. Since most households will eventually face a diarrhea episode, restricting to only households that had a recent episode might provide a clearer picture of the long term effect.

Table 20 presents means of the coverage, take-up, and compliance metrics by group assignment and reports statistical differences between groups. When I only include households with a diarrhea episode (top panel), take-up in the Free+Delivery group was highest (82%), particularly take-up from the CHP (65%). Take-up in the Free+Delivery group was higher than take-up in the Voucher group although differences were not statistically significant (p=.115 for total take-up and p=.149 for take-up from CHP). Compliance is high in all groups ($\sim$ 90%), suggesting that wastage of ORS is not a big concern if child has a case of diarrhea. Compliance is slightly higher in the Voucher group (3 percentage points) but not significantly different from Free+Delivery (p=.39). Compliance in the Home Sales group is also higher than Free+Delivery (6 percentage points) and the differences are statistically significant at the 10% level (p=.06), suggesting that charging could help target to compliers.

When I include households with no recent diarrhea case, the differences in take-up between Free+Delivery and the other groups becomes more extreme, suggesting that take-up among households with no case of diarrhea was larger in the Free+Delivery group. Moreover, compliance is substantially larger in all groups relative to Free+Delivery, indicating that Free+Delivery leads to larger amounts of unused ORS after one month.

It is also possible that households in the Free+Delivery group received larger quantities of ORS conditional on take-up (we instructed CHP's to deliver two packets per child), which would imply that the difference in unused ORS is more extreme than the difference in compliance. To estimate unused ORS packets, I compare care-taker reports of number of ORS packets obtained to number of ORS packets used. I then use ordinary least squares to estimate differences in unused ORS with standard errors clustered by village (Table 21). Among households with a diarrhea episode, Free+Delivery led to a .71 and .73 increase in unused ORS packets per household, relative to the control and Home Sales group. This implies that the Free+Delivery group received more packets conditional take-up, since there was no clear difference in compliance in the sample with a diarrhea episode. There was no difference in unused packets between the Free+Delivery and Voucher groups. When I include all households, the difference in unused packets is accentuated, with Free+Delivery having more unused packets per household than all other groups. Although it's unclear how much of this unused ORS will eventually be used once a diarrhea case occurs, it is clear that both Vouchers and Home Sales do a better job a targeting ORS to households that have a diarrhea episode, leading to less unused ORS in those groups after one month.

8.4 Summary of Implications for Wastage

These results imply that compliance is not a big concern if a child has a case of diarrhea. Moreover, Free+Delivery does not appear to increase distribution to caretakers with a lower propensity to use ORS if presented with a case of diarrhea. However, Free+Deliver does a worse job of targeting ORS to households with a diarrhea episode than Home Sales or Vouchers (by design), which could lead to more unused ORS in the short term. If all households eventually have a case of diarrhea, then the difference in targeting to compliers and unused ORS could diminish. Moreover, having ORS stored in the home might increase the probability of future use. On the other hand, as time passes without an episode, households might be more likely to lose or damage their packets. Since requiring households to retrieve ORS from the CHP's home leads to less unused ORS without sacrificing coverage, this could be a more efficient strategy for distributing free health products. This result is consistent with Dupas et al. (2016).

8.5 Limitations

This analysis has important limitations. First, I am underpowered to assess equality (i.e. precise zeros) of coverage, take-up, or compliance between any two study arms, which is a criterion for scenarios 2 and 3 of the conceptual framework. For example, the confidence interval of the coverage difference between Free+Delivery and Vouchers includes important differences on the upper end (9 percentage points), which means I can't rule out that Free+Delivery actually does a better job of increasing coverage than Vouchers. Moreover, since ORS is extremely cost-effective, even very small differences in coverage are important, yet I am not powered to detect these differences. Second, I don't know what the long term effect on unused packets or coverage will look like since all unused packets could eventually be used. Future work should assess the impact of these interventions over a longer time horizon to get a more accurate assessment of efficiency at scale-up. Finally, although this section assesses the trade-offs between compliance and coverage, it does not fully assess which intervention allocates resources in the most efficient way. Since ORS is extremely cheap from the donor perspective, unused ORS does not have a large effect on cost-effectiveness ratios. Moreover, there are other costs that should be considered such as out-of-pocket costs to the households. In order to fully assess the efficiency of each intervention, I conducted a cost-effectiveness analysis, which is documented in the next section.

9 Cost-Effectiveness

9.1 Overview

In order to compare the efficiency of each intervention, I conducted a cost-effectiveness analysis from the perspective of BRAC (including only BRAC's program costs) and from a societal perspective (including BRAC's cost and costs incurred by the household). I estimated incremental cost-effectiveness ratios (ICERs) both in terms of cost per additional case treated with ORS and cost per disability adjusted life-year (DALY) averted. I used a time horizon of 1-month (the length of time between intervention and endline) and included all households for this analysis (including households with no case of diarrhea). I only considered treatment costs and benefits of ORS use (excluding costs and benefits of zinc) since the health benefits of zinc alone and zinc added to ORS are less well documented.

9.2 Costs

9.2.1 Program Costs

The status quo is for BRAC to purchase ORS packets from a supplier for about \$0.07 (USD) and to sell to CHPs for about \$0.05 (USD). Therefore, BRAC incurs a cost of about \$0.02 per packet distributed. In the three intervention scenarios, BRAC incurs the full cost of ORS (i.e. \$0.07). To estimate BRAC's program costs, I used the household survey data to identify the number packets acquired from the CHP by each household and multiplied this number by the cost per packet incurred by BRAC for the respective intervention group. I then estimated the average cost per household for each of the four groups. Finally, I multiplied the average cost per household by the population size of the control group (to keep the population size consistent across groups). Row 1 of Table 23 presents monthly program cost estimates by group assignment. Free+Delivery was the most costly at about \$280 to distribute ORS to 1,939 households. This is because take-up from the CHP was highest in this group. Vouchers was the next most costly and was only slightly less expensive than Free+Delivery. Home Sales and the control group were cheapest at only \$84 and \$9 dollars, respectively. Costs are so low in these groups since only 21% and 7% of households took up ORS, respectively.

9.2.2 Household Costs

The household survey recorded the time spent by caretakers seeking treatment for each case of diarrhea, the amount spent on clinic fees, the amount spent on treatment, and the amount spent on transport. I used these questions to estimate the average cost to household in each group. To estimate the cost of caretaker time, I used the monthly wage for paid female workers reported in the Uganda Living Standard and Measurement Survey, which is about \$44 (USD) (Uganda Bureau of Statistics, 2012). I then divided this number by 20 (working days per month) and then by 8 (work hours per day) to get the average hourly wage for women in Uganda (about \$0.27). I then multiplied the hourly wage by the time spent seeking treatment to estimate the cost of time spent seeking treatment for each household. I then repeated the same process documented in section 9.2.1 (average cost per household X population size) to get total cost of time for each group. Table 23 shows that the cost of time spent seeking treatment was substantially lower in the Free+Delivery group than all other groups. This is because caretakers in the Free+Delivery were less likely to have to leave the home to seek treatment. The cost of time spent seeking treatment was highest in the control group, which is consistent with this group being the least likely to seek treatment from the CHP and the most likely to seek treatment outside the home. These results are consistent with treatment seeking reports documented in Table 3.

Treatment, clinic and transport cost were all reported directly by the caretakers. For each of these categories I took the average cost per household and multiplied by the population size to get total costs per group. Both of the free distribution groups had substantially lower clinic, treatment, and transport costs then the two charging groups (Table 23).

9.3 Benefits

Since I include households without a case of diarrhea, all households contribute to the program costs, but only households with a diarrhea episode contribute to the benefits. This assumes that there is no benefit to receiving ORS if there was no diarrhea episode in the prior 4 weeks. Therefore, the benefits in the free distribution groups, where there was more distribution to households with no diarrhea episode, are understated if unused ORS eventually gets used.

9.3.1 Cases Treated

To estimate the number of diarrhea cases treated with ORS for each scenario, I used the number of cases treated in the control group combined with the effectiveness of each intervention on increasing ORS coverage (reported previously in Table 5). I use the following equation.

$$CT_{cntl} = Population \times Pr(Diarrhea) \times Pr(ORS|Diarrhea) \quad (6)$$

$$CT_j = Population \times Pr(Diarrhea) \times (Pr(ORS|Diarrhea) + Eff_j)$$

Where CT_{cntl} and CT_j are the number of cases treated in the control group or intervention group j, respectively, and Eff_j is the effectiveness of intervention j in terms of increasing ORS use.

9.3.2 Deaths and DALYs Averted

To estimate the number of deaths in each group, I first estimated the probability of death conditional on having a diarrhea episode. I used 2015 data on births and deaths due to diarrhea from Liu et al. (2015). I assumed that each child has 5 episodes of diarrhea per year (estimated from study data) and that deaths only occurred among cases not treated with ORS (54% of cases in Uganda). This gives the following formula for probability of death.

$$Pr(Death|Diarrhea) = \frac{Deaths}{Births * CasesYear * .54} \quad (7)$$

I then use Munos et al. (2010) for estimates of the effectiveness of ORS, which is a systematic review that documents a 93% reduction in diarrhea mortality as a result of ORS use. This gives the following weighted average to estimate the number of deaths for each group.

$$Deaths_j = (Pr(Death) \times (Cases_j^{NoORS})) + (Pr(Death) \times (1 - Eff_{ors}) \times (Cases_j^{ORS}))) \quad (8)$$

Where $Cases_j^{NoORS}$ and $Cases_j^{ORS}$ are number of cases treated without and with ORS, respectively, for group j. Eff_{ors} is th effectiveness of ORS (i.e. 93% reduction in mortality risk). Therefore, the first term represents deaths among cases not treated with ORS, and the second term represents deaths among cases treated with ORS.

To convert deaths in into DALYs averted, I used the life expectancy in Uganda (59 years) combined with the average child age in my sample (24 months), to first estimate the life-years saved for each death averted. I discounted future life years gained at 3%, which gives about 27.15 discounted life years saved for each death averted. Since diarrhea does not have a large effect on disability, I ignore the potential reductions in disability that result from increased ORS use and assume all of the DALYs averted come from life years saved. This produces a conservative estimate of DALYs averted. I used the following equation for DALYs averted.

$$DA_{j,i} = \sum_{t=0}^{57} \frac{(Deaths_i - Deaths_j)}{1.03^t} \quad (9)$$

Where $DA_{j,i}$ is the DALYs Averted for intervention j relative to intervention i. The numerator is the deaths averted by intervention j relative to intervention i, which is summed over 57 additional years of life, and the denominator applies discounting for life years gained in the future.

9.4 Parameter Ranges

The parameters used for my cost and benefit estimates, including sensitivity ranges, are included in Table 22. For estimates that are taken from the study data and for ORS effectiveness, I used the upper and lower bounds of 95% confidence intervals, with the exception of ORS costs. I used a wider range of ORS costs (+/- 20%) to allow for addition distribution cost that might arise at scale-up (e.g. increased contact with the supplier or more transportation costs). For probability of death, I used upper and lower bounds of number of deaths provided by Liu et al. (2015). For hourly wage, I increased and decreased the base wage by 10%.

9.5 Results

Table 24 presents the incremental cost of each intervention relative to the next most expensive intervention. From the implementer perspective (BRAC's perspective) the incremental costs are relatively small, since ORS is so cheap. From a societal perspective, Free+Delivery is cost saving relative to all other interventions, since households in this group incur far fewer out-of-pocket costs. The control group is most expensive from a societal perspective.

Table 25 presents incremental benefits and ICERs from the implementer perspective (since Free+Delivery is the most effective and least expensive from a societal perspective, ICERs are not applicable). The top panel presents incremental gains and ICERs relative to the next best alternative and the lower panel compares Free+Delivery to the other two groups.

Cases Treated
There were 337 cases treated with ORS in the control group. The Home Sales intervention resulted in 50 additional cases treated with ORS at \$1.51/case. An additional 56 cases treated could be achieved with the Voucher intervention at a cost of \$2.37/case relative to Home Sales. Free+Delivery achieved another 18 cases treated at \$3.56/case relative to Vouchers. It's important to keep in mind that the effectiveness of Free+Delivery was not statistically different from Vouchers, and therefore this last estimate should be interpreted with caution.

Free+Delivery achieved an extra 120 and 74 cases treated relative to the control and Home Sales scenarios, at \$2.20 and \$2.66 per case, respectively. All interventions are relatively low cost and extremely cost-effective in terms of cases treated. Since Free+Delivery is the most effective, and still likely within most budgets (since it is so cheap), this strategy would be the appropriate choice.

Deaths and DALYs Averted
I estimated that .39 children were expected to die under the status quo scenario (i.e. the control group). The Home Sales intervention reduced deaths by .07, which converts to 1.7 DALYs averted and costs \$44 per DALY averted. An additional .07 deaths could be averted under the Voucher intervention, leading to 1.92 DALYs averted at a cost of \$69 per DALY averted. Finally, going from the Voucher intervention to the Free+Delivery intervention adds and additional .02 deaths averted leading to .61 DALYs averted at a cost of \$104 per DALY averted. When compared to the control group, Free+Delivery averts 4.24 DALYs at a cost \$64 per DALY averted. When compared to the Home Sales group, Free+Delivery averts 2.53 DALYs at a cost \$77 per DALY. All interventions are extremely cost-effective in terms of DALYs averted and well below any traditional cost-effectiveness threshold (<GDP per capita—\$675 in Uganda—is considered extremely cost-effective). Again Free+Delivery is the appropriate choice of distribution strategy.

9.6 Sensitivity Analysis

9.6.1 Importance of Each Parameter

Next, I conducted a one-way sensitivity analysis to identify the parameters to which the above results were most sensitive. For each parameter, I used the upper and lower bounds of the ranges from Table 22 and re-estimated the ICERs. The first result is that, from a societal perspective, Free+Delivery was cost saving relative to all other scenarios even when using upper or lower bound cost estimates. The cost of Free+Delivery would have to be underestimated by at least 27-56% (depending on the reference scenario) in order for it not to be cost saving.

Table 26 presents the upper and lower bounds for each of the donor perspective ICERs from Table 25 produced from this exercise, along with the parameter that produced the boundary. For Home Sales vs. the control group, the results were sensitive to the effectiveness of Home Sales. Since the confidence interval neared zero, the upper bound of the ICER was very large. The ICER for Free+Delivery vs. Vouchers was sensitive to both the effectiveness of Free+Delivery and the probability of death from a diarrhea episode. With the lower bound of Free+Delivery effectiveness, Free+Delivery was dominated by Vouchers (more expensive and less effective). The other ICERs were also most sensitive to the probability of death and intervention effectiveness, although they all remained low and conclusions remained unchanged.

Figure 10 presents ranges of the ICER of Free+Delivery relative to the control group for the 6 parameters that can influence this estimate: cost in control group, Pr(Diarrhea), cost of Free+Delivery, effectiveness of ORS, effectiveness of Free+Delivery, and Pr(Death|Diarrhea). The probability of death conditional on a diarrhea episode was the parameter that produced the largest range for this ICER. However, the this partly due the uncertainty of this estimate and the wide parameter range examined.

9.6.2 Cost-Effectiveness Using Demand Side-Price Effect

So far, this analysis has aimed to understand the relative cost-effectiveness of the three different ORS distribution strategies, which include both supply and demand side effects. However, it is also important to understand the cost-effectiveness of the demand side response to ORS use invoked by receiving free ORS rather than facing the market price. This will provide insight for programs that do not distribute ORS through CHW networks and thus are not interested in including the CHW response, but rather only the household response to different prices. To identify the cost-effectiveness of a household receiving ORS for free rather facing the market price, I used the analysis from section 7.5 and estimates from Table 16. This analysis isolates the demand side price-effect by comparing Free+Delivery to Home Sales, while controlling for CHP visits. As I discussed in that section, my estimate is likely a lower bound due to the endogeneity of CHP visits. If I use this demand side price-effect of 6.3 percentage points (rather than 12.3 percentage points) I find that the demand side effect of receiving ORS for free rather than facing the market price produces 36 more treated cases at $5.39 per case treated and averts 1.25 DALYs at $157 per DALY averted. Therefore, only invoking the demand side response from free distribution is still very cost-effective.

9.7 Summary of Cost-Effectiveness

All interventions were relatively low cost and extremely cost-effective in terms of both cases treated and DALYs averted. The Free+Delivery arm was the most effective and had an ICER below any potential budget or cost-effectiveness threshold, indicating that it is the preferred strategy from an implementer perspective. At only $64 per DALY averted relative to the control group, the Free+Delivery intervention is on par with the most cost-effective maternal and child health interventions available (Black et al., 2016). Moreover, Free+Delivery was cost-saving relative to all other scenarios from a societal perspective.

9.8 Limitations

This analysis is limited in a similar way as the prior section. First, without estimating the long term costs and benefits, these estimates could be misleading. However, since the cost of ORS obtained by households without a diarrhea episode are included in this analysis, whereas the potential future benefits of having these packets stored are not included, I expect the long-term cost-effectiveness of the free distribution interventions (particularly the Free+Delivery group) to be understated. If these households eventually have a diarrhea episode, the unused ORS could be used to treat these future cases.

Second, ORS is likely to produce less health benefits for less severe cases of diarrhea. Although I don't find statistically significant evidence that Free+Delivery expands ORS to less severe episodes, I do find large (imprecise) point estimates (Table 12). If the additional cases treated under Free+Delivery are less severe, health gains could be over-stated. However, even when I assume that the effectiveness of ORS is smaller for the additional cases treated by the Free+Delivery intervention by using the lower bound of ORS effectiveness for only these cases, the cost per DALY averted is still $86 and $137 relative to the control and Home Sales groups, respectively.

Third, I did not include CHP time spent making the households visits as part of the costs for several reasons. First, since BRAC does not compensate CHPs, this is not part of program costs. Second, any training costs are constant across scenarios, since CHPs receive monthly refresher trainings. Third, CHPs are supposed to visit every household each month under the status quo, and it is unclear how much additional time (if any) is spent by CHPs in the treatment groups. Moreover, I do not have a good estimate of CHP time spent carrying out the intervention. That said, if I do include CHP time costs and assume it takes 3 days to carry out the household visits (most CHPs suggested they could do it in less time), this only adds about $200 to the societal cost of each of the treatment arms, assuming the hourly wage from Table 22. Since adding $200 does not change the societal cost ranking of any of the scenarios (aside from Home Sales and Control), including CHP time costs does not change my conclusions. For example, even if I assume only CHPs in the Free+Delivery arm had time costs, this intervention is still cost-saving relative to all other interventions.

Fourth, it is possible that additional program costs will arise at scale-up. For example, BRAC's branch managers might have to spend more time talking to ORS suppliers and there might need to be more frequent transportation from the main headquarters to the local branches. However, even when I increase the cost of Free+Delivery by 20% in the sensitivity analysis the cost-effectiveness of Free+Delivery is still well below any plausible cost-effectiveness threshold. The program costs of Free+Delivery would have to increase 10-fold in order for the cost per DALY averted to approach the "extremely cost-effective" threshold of <GDP per capita ($675/DALY averted in Uganda).

Fifth, I do not include the benefits of increasing zinc use in this analysis since the health gains from zinc are less well documented. However, the Third Edition of Disease Control Priorities ranks zinc added to ORS as the second most cost-effective intervention for maternal and child health (Black et al., 2016). Moreover, Free+Delivery increased ORS+zinc use by even more than ORS use. Therefore, including the benefits of zinc would improve the cost-effectiveness Free+Delivery.

Finally, I do not include the incentive given to CHPs as part of the program costs, since this would not be provided upon scale-up. If I do include these costs ($450 total for each of the three treatment groups), Free+Delivery is still cost saving relative to the other groups. However, if these incentives are an important factor in program effectiveness, the effectiveness at scale-up could be smaller, which would increase the ICERs of Free+Delivery.

10 Discussion

This study provides evidence that free distribution of ORS and zinc by CHWs can substantially increase coverage of these products relative to charging. I show that both free preemptive delivery (Free+Delivery) and free distribution from the CHP's home (Vouchers) increased the share of diarrhea cases treated with ORS and ORS+zinc relative to a control group (where CHPs charge a fee) and a door-to-door sales group (Home Sales). These results suggest that price is an important barrier to ORS and zinc use in Uganda.

I find no difference in ORS and zinc use between Free+Delivery and Vouchers, suggesting that convenience is not an important barrier to use. Most caretakers appear to have been willing to endure the small hassle cost of retrieving the free ORS and zinc from the CHP's home if their child had a diarrhea episode. Over half of caretakers lived within a 5-minute walk to the CHP's home and it is possible this short distance was not enough of a hassle cost to dampen demand. Convenience of access could be a barrier in less densely populated areas, where retrieval costs are larger. I find no evidence that caretakers living further away from the CHP's home are less likely to redeem vouchers, however this study was not powered for such an analysis (available upon request).

Among households without a diarrhea episode, I find that demand was significantly lower in the Voucher group than the Free+Delivery group, suggesting that retrieval costs screened out households that did not have a current need for ORS. This is consistent with Dupas et al. (2016), who find that imposing retrieval costs for point-of-use water treatment reduced demand without affecting use, implying a reduction in wastage. Wastage implications for this study are less clear, since ORS packets that go unused after one month due to lack of a diarrhea episode could be used in the future. Moreover, I find that 89% of caretakers that obtained an ORS packet via Free+Delivery and had a child with diarrhea episode used the ORS, and compliance was similar in the Voucher group. Therefore, Vouchers did not appear to improve targeting to compliers conditional on a diarrhea episode. Since most children will eventually have a diarrhea episode, it is likely that many of the unused ORS packets will be used in the future, an if so, wastage of ORS under Free+Delivery is not big concern. Vouchers could be more efficient for health products where average adherence is lower, and wastage is more common.

Although the price of ORS and zinc appears to be a barrier to use for the caretaker, these products are very cheap from a donor perspective. It costs only about $10 per village per month (ORS costs only) to implement the Free+Delivery program. This results in very low cost-effectiveness ratios of both Free+Delivery and Vouchers. At well under $200 per DALY averted, this puts free distribution of ORS (relative to charging) on par with the most cost-effective maternal and child health interventions available (Black et al., 2016). Although both Free+Delivery and Vouchers are similarly cost-effective from a donor perspective, I find that the additional retrieval costs incurred by Voucher households relative to Free+Delivery households, makes Free+Delivery cost saving from a societal perspective, and thus is the most efficient distribution strategy.

This work suggests that having CHPs provide ORS and zinc for free could substantially increase coverage and reduce deaths from diarrhea relative to charging. If all of BRAC's 3,000 CHPs in Uganda that require purchase of ORS and zinc switched to free distribution, this would result in about 14,400 additional cases treated with ORS and 19 lives saved per month.[12] Moreover, in villages where CHPs are already working, this would be an easy intervention to implement. CHPs are already instructed to visit households with a child under-5 each month and they visit the BRAC office each month for refresher trainings and restocking of health products. Therefore, this intervention only requires slightly more effort administratively and from CHPs. Qualitative evidence from discussions with CHPs suggest the they enjoy giving these products away for free. Moreover, quantitative evidence on CHP effort suggest that they are willing to carry out the deliveries.

However, it is not clear that the effectiveness of free distribution after one month will carry over if scaled-up. It is possible that over time, CHPs could stop making deliveries or reduce the frequency of household visits. Moreover, the salience effect induced by the initial delivery of ORS and vouchers could wear off over time and caretakers could revert back to old habits. Future work should exam the impact of these interventions over a longer time horizon.

Although this study suggests that free distribution of health products could be an optimal strategy, it is not clear how well the results from this study translate to other health products.

[12]Assuming 3,000 villages with 24 cases per village per month, this would be 72,000 cases per month. Under the status quo, 56% of cases get treated with ORS and under Free+Delivery 76% of cases get treated. This give additional cases treated as 72,000*.76-72,000*.56=14,400. Using the case specific death rate .0014, this means 20.16 of these 14,400 children would die under the status quo (14,400*.0014=20.16). However, applying the effectiveness of ORS only 1.4 of these 14,400 children would die under Free+Delivery (14,400*.0014*.07=1.4).

ORS is extremely cheap, extremely effective, and compliance appears to be fairly high. The cost of distributing more expensive products for free would be higher and could produce weaker health gains. However, there is a growing body of literature suggesting that free distribution of other health products (e.g. point-of-use water treatment, bed nets, and deworming medication) is also preferred to charging (Kremer et al., 2011a).

Another interesting finding from this study is that assignment to one of the free distribution groups increased CHP effort (measured by household visits). This finding is counterintuitive since CHPs in the Home Sales group were allowed to keep the revenue from any sales. Therefore, neoclassical economic theory would predict that CHPs assigned to Home Sales would exert more effort. This finding contributes to the literature on how to best motivate community health workers. Ashraf et al. (2014) demonstrate that non-financial or social incentives lead to improved effort from health workers over financial incentives. Deserranno (2014) finds that the type of women that become CHPs are particularly socially motivated. This suggests that allowing health workers to provide products for free could improve health worker motivation in addition to increasing coverage, relative to charging.

This work contributes to a sparse literature on the barriers to ORS use and what works to increase use. This is the first study to examine the role of price and convenience in ORS use and how overcoming these barriers affects use. The results imply that efforts to increase access to free ORS should be expanded. Although this study focuses on one CHW program, there are many other ways to ensure that households have access to free ORS. For example, public health facilities could provide all caretakers of children under-5 with large quantities of free ORS for future use during well-child check-ups. New mothers could be endowed with ORS at post-natal check-ups. Public-private partnerships could incentivize private providers to provide free ORS. Governments and NGOs dedicated to increasing use of ORS should focus on new ways of making sure caretakers have access to free ORS.

11 Conclusion

ORS and zinc are extremely effective at preventing mortality from diarrhea, yet they remain largely under-used. As a result, children continue to die by the hundreds of thousands. This research demonstrates that having CHWs provide these products for free rather than charging has the potential to save many of these lives. Implementers of CHW programs should consider free distribution of ORS and zinc.

12 Research Team

This project is led by Zachary Wagner and John Bosco Asiimwe under the supervision of William H. Dow and David I. Levine.

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13 Figures

Figure 1: Randomization Flow Diagram

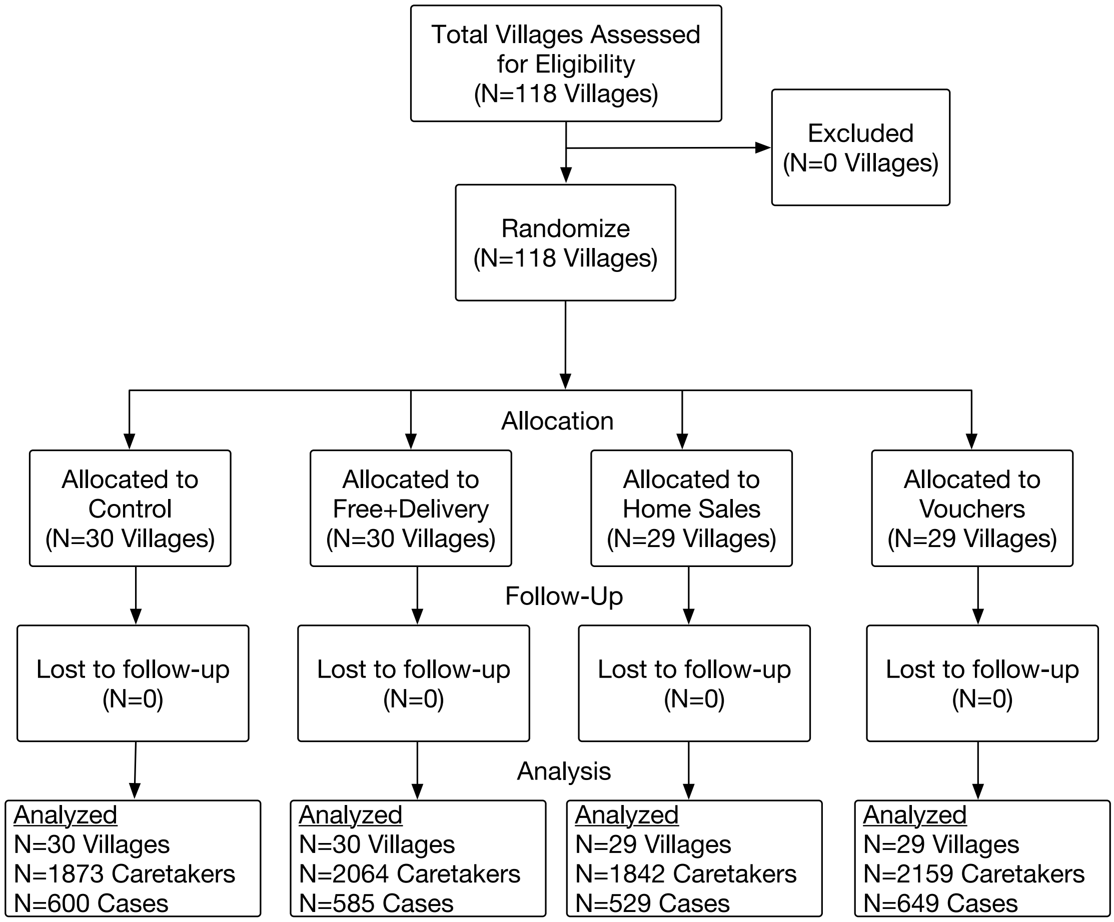


Figure 2: Map of Study Villages

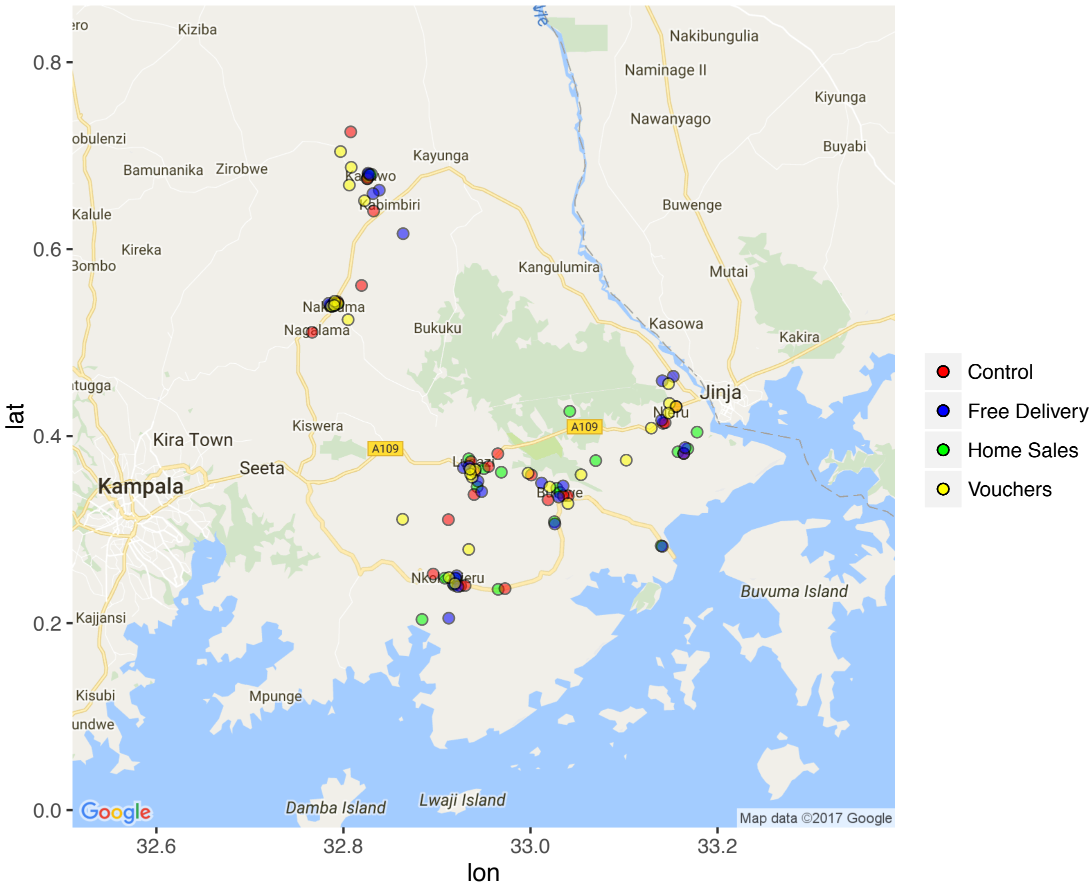
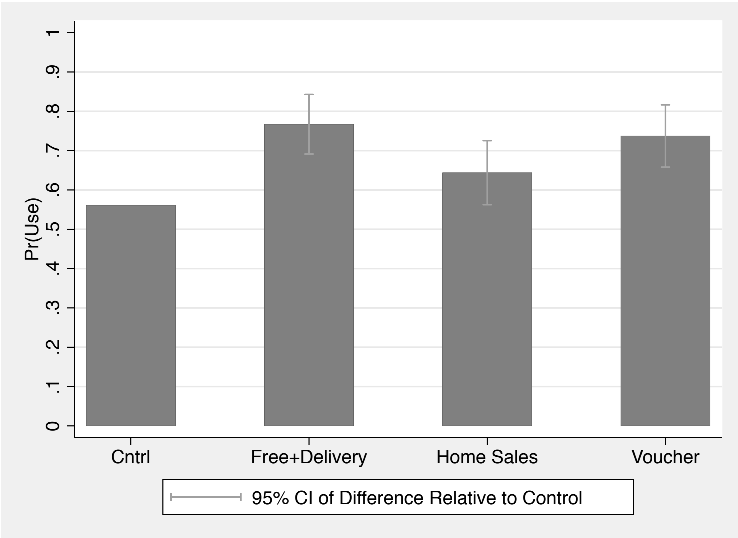
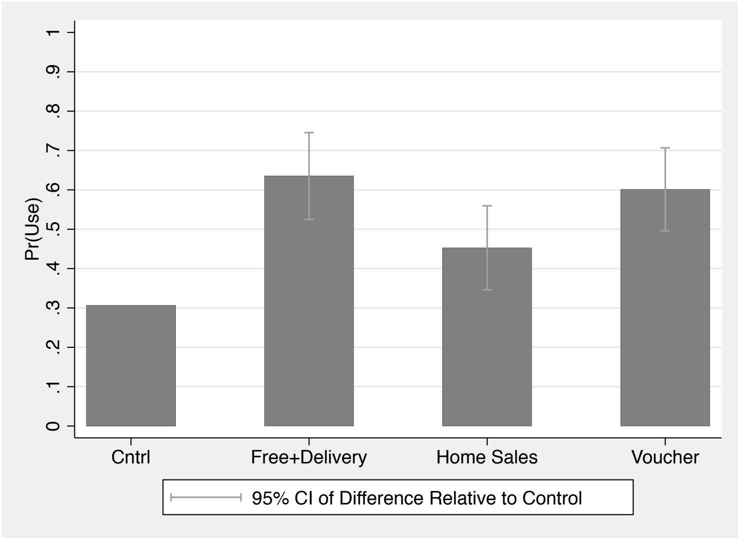


Figure 3: Share of Cases Treated with ORS



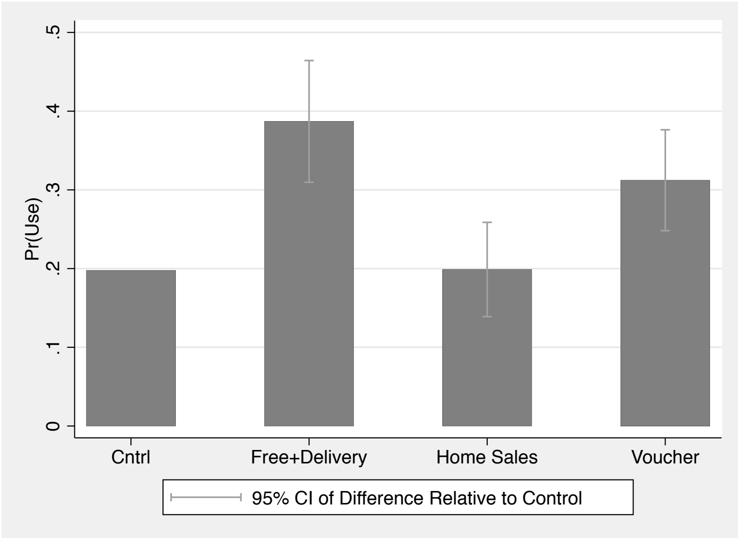
95% CIs are marginal effects estimates from logit regressions with village clustered standard errors

Figure 4: Share of Cases Treated with ORS+Zinc



95% CIs are marginal effects estimates from logit regressions with village clustered standard errors

Figure 5: Share of Cases Treated With ORS on Same Day as Diarrhea Initiation



95% CIs are marginal effects estimates from logit regressions with village clustered standard errors

Figure 6: Kaplan-Meier Estimates of ORS Use Over Time

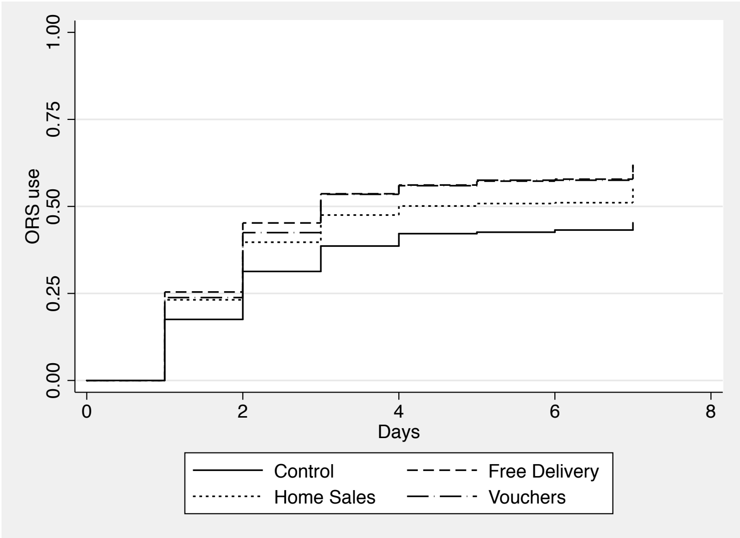
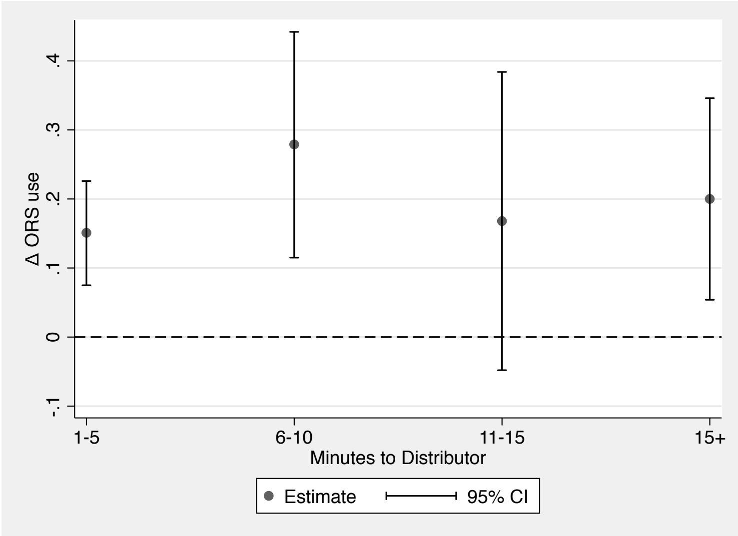


Figure 7: Heterogeneity in Impact of Free+Delivery by Distance to Nearest Distributor (Relative to Control)



Estimates are from 4 separate logit regressions with village clustered standard errors. Interaction models show that there is no statistical difference in treatment effects between any level of distance

Figure 8: Endline ORS Use by Baseline ORS Use (Lowess smoothed estimates)

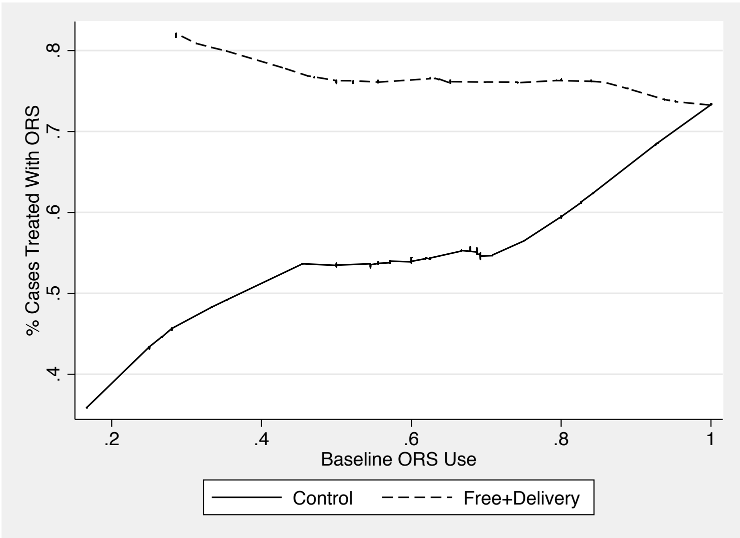
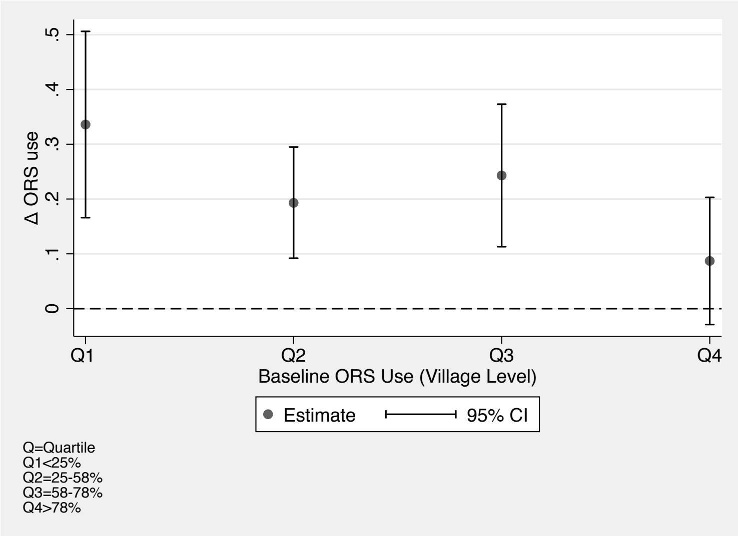
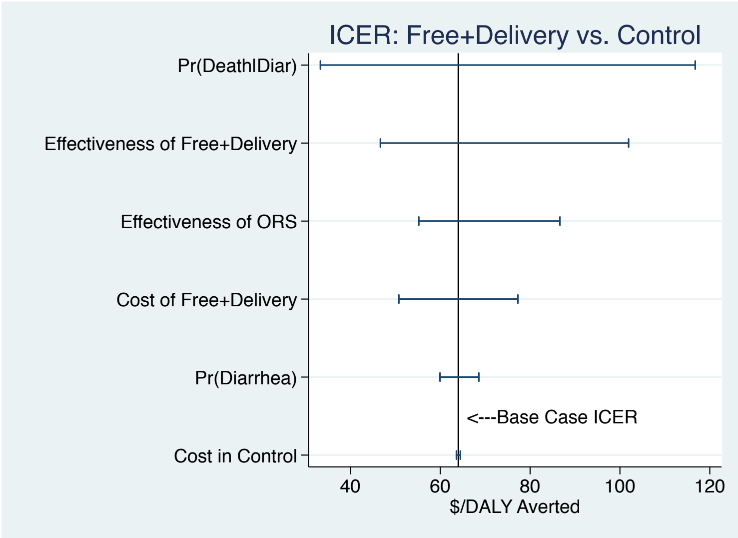


Figure 9: Impact of Free+Delivery by Village Level ORS Use at Baseline



Estimates are from 4 separate logit regressions with village clustered standard errors. Interaction models show that the treatment effect is statistically different between Q1 and Q4 (interaction term=.249; p=.018) and between Q3 and Q4 (interaction term=.156; p=.079)

Figure 10: One Way Sensitivity Analysis



Estimates based on changing each parameter individually to upper and lower bound. Parameters included are only parameters that influence this ICER

14 Tables

Table 1: Balance Between Groups (Exogenous Variables Assessed at Endline)

	(1) Control	(2) Free+Delivery	(3) Home Sales	(4) Vouchers
Number of Villages	30	30	29	29
Number of Caretakers	1873	2064	1842	2159
Caretakers w/ Diarrhea Case	534	529	480	579
% of Caretakers w/ Diarrhea Case	.285	.256	.261	.268
Total Diarrhea Cases	600	585	529	649
Caretaker Characteristics				
Caretaker Age	28.5	30.1^{*}	$28.3_{\dagger\dagger}$	29.7
Number of Children	2.87	3.08	3.00	3.14^{**}
Education				
None	.08	$.118^{*}$	$.055^{*}_{\dagger\dagger}$	.094
Primary	.542	$.456^{**}$	$.465^{*}$	.484
Secondary+	.378	.426	$.48^{**}$	.422
Wage Work Last 7 Days	.553	.508	$.618_{\dagger\dagger}$	.521
Child Characteristics				
Child Age (Months)	22.9	23.9	22.2	24.3
Male	.538	.544	.529	.533
Diarrhea Case Every Month	.292	.241	.27	$.233^{*}$
Blood in Stool	.07	.058	$.106^{*}_{\dagger\dagger\dagger}$	.062
Concurrent Fever	.553	.513	.563	.573
Household Characteristics				
Water Source				
Piped	.142	.185	.238	$.271^{*}$
Protected Well	.693	.684	.578	.561
Unprotected Source	.133	.096	.129	.134
Main Income Source				
Agriculture	.168	.21	.142	.237
Public Sector	.013	.014	.026	.018
Private Sector	.202	$.118^{**}$	$.195_{\dagger\dagger}$	.177
Informal	.513	.533	.552	.451

Includes endline data for households with a case of diarrhea

Unit of observation=Child

$***p < .01, **p < .05, *p < .1$ relative to control

$\dagger\dagger\dagger p < .01, \dagger\dagger p < .05, \dagger p < .1$ relative to Free+Delivery

p-values correct for clustering at the village level

Marginal effects assessed with OLS for continuous and Logit for binary outcomes

Multinomial logit test for joint orthogonality produces p-value from χ^2-test <.001

Diarrhea case every month=caretaker reported that child has diarrhea 1+ times per month

Table 2: Balance Between Groups (Endogenous Variables Assessed at Baseline)

	(1) Control	(2) Free+Delivery	(3) Home Sales	(4) Vouchers
Number of Villages	30	30	29	29
Number of Caretakers	1197	1198	1195	1152
Caretakers w/ Diarrhea Case	397	400	397	343
% of Caretakers w/ Diarrhea Case	.332	.334	.332	.298
Total Cases	453	474	451	392
Used ORS for Recent Case	.625	.645	.596	.61
Used ORS+Zinc for Recent Case	.366	.374	.308	.355
ORS Same Day as Initiation	.258	.308	.275	.23
Used Antiotic for Recent Case	.108	.096	.111	.087
Ever Used ORS	.879	.838	.843	.875
Ever Used Zinc	.55	.498	.479	.538
Heard of ORS	.965	.954	.953	.985$_{\dagger}$
Heard of Zinc	.753	.646**	.685*	.73$_{\dagger\dagger}$
Free ORS in Village	.302	.257	.359	.324
Free Zinc in Village	.194	.158	.226	.24
Visited by CHP Last 4 Weeks	.364	.447	.324	.37

Includes only pre-intervention data

$***p < .01, **p < .05, *p < .1$ relative to control

$\dagger\dagger\dagger p < .01, \dagger\dagger p < .05, \dagger p < .1$ relative to Free+Delivery

p-values correct for clustering at the village level

Unit of observation=Child

Multinomial logit test for joint orthogonality produces p-value from χ^2-test =.24

Table 3: Intermediate Outcomes (Last 4-Weeks)

	(1) Control	(2) Free+Delivery	(3) Home Sales	(4) Vouchers
Exposure				
Free Delivery of ORS	.031	.605***	.098$^{***}_{\dagger\dagger\dagger}$	.176$^{***}_{\dagger\dagger\dagger}$
Home Sales Offer	.081	.119	.194$^{***}_{\dagger}$	.119
Received Voucher	.022	.044	.024	.424$^{***}_{\dagger\dagger\dagger}$
Take-Up and Storage				
Obtained any ORS	.247	.701***	.372$^{***}_{\dagger\dagger\dagger}$	.543$^{***}_{\dagger\dagger\dagger}$
Obtained ORS from CHP	.071	.634***	.211$^{***}_{\dagger\dagger\dagger}$	.457$^{***}_{\dagger\dagger\dagger}$
Free ORS from CHP	.046	.633***	.113$^{***}_{\dagger\dagger\dagger}$	.449$^{***}_{\dagger\dagger\dagger}$
ORS Delivered by CHP	.039	.607***	.161$^{***}_{\dagger\dagger\dagger}$	.181$^{***}_{\dagger\dagger\dagger}$
ORS Stored: Currently	.106	.531***	.215$^{***}_{\dagger\dagger\dagger}$	.376$^{***}_{\dagger\dagger\dagger}$
ORS Stored: Diarrhea Episode	.085	.503***	.157$^{**}_{\dagger\dagger\dagger}$	.333$^{***}_{\dagger\dagger\dagger}$
Obtained any Zinc	.147	.671***	.281$^{***}_{\dagger\dagger\dagger}$	.497$^{***}_{\dagger\dagger\dagger}$
Free Zinc from CHP	.042	.628***	.102$^{**}_{\dagger\dagger\dagger}$	.436$^{***}_{\dagger\dagger\dagger}$
Zinc Delivered by CHP	.039	.607***	.161$^{***}_{\dagger\dagger\dagger}$	.181$^{***}_{\dagger\dagger\dagger}$
Zinc Stored: Currently	.087	.564***	.199$^{***}_{\dagger\dagger\dagger}$	.400$^{***}_{\dagger\dagger\dagger}$
Zinc Stored: Diarrhea Episode	.068	.481***	.112$^{*}_{\dagger\dagger\dagger}$	.310$^{***}_{\dagger\dagger\dagger}$
Treatment Seeking				
CHP visit	.237	.61***	.355$^{**}_{\dagger\dagger\dagger}$	.553***
Visit CHP home	.187	.272*	.229	.441$^{***}_{\dagger\dagger\dagger}$
Sought Treatment Out of Home	.658	.526***	.705$_{\dagger\dagger\dagger}$	.666$_{\dagger\dagger\dagger}$
Sought Treatment (Non-CHP)	.598	.352***	.544$_{\dagger\dagger\dagger}$	.39***

$* * *p < .01, * * p < .05, *p < .1$ relative to control

$\dagger\dagger\dagger p < .01, \dagger\dagger p < .05, \dagger p < .1$ relative to Free+Delivery

Visit CHP Home=caretaker visited CHP's home in last 4 weeks

p-values correct for clustering at the village level

ORS Stored: Diarrhea Episode=ORS stored at home when diarrhea episode began

CHP Visit=CHP Visited the household in the last 4 weeks

Sought Treatment=Caretaker sought treatment outside of the home

Table 4: Diarrhea Treatment For Case in Last 4 Weeks (Endline)

	(1) Control	(2) Free+Delivery	(3) Home Sales	(4) Vouchers
Used ORS	.561	.767***	.644$^{**}_{\dagger\dagger\dagger}$	.737***
Started ORS Same Day	.198	.387***	.199$_{\dagger\dagger\dagger}$	.312$^{***}_{\dagger}$
Used Zinc	.375	.67***	.519$^{**}_{\dagger\dagger\dagger}$	.648***
Used ORS+Zinc	.307	.635***	.453$^{***}_{\dagger\dagger\dagger}$	.601$_{\dagger\dagger\dagger}$
Used Antibiotic	.263	.193*	.242	.153***

$***p < .01, **p < .05, *p < .1$ relative to control

$\dagger\dagger\dagger p < .01, \dagger\dagger p < .05, \dagger p < .1$ relative to Free+Delivery

P-values not adjusted for multiple outcomes

See Table 6 and 7 for adjusted p-values

Same Day= Same day as start of diarrhea episode

Table 5: Impact On ORS Use for Case of Diarrhea in Last 4 Weeks

	ORS Use	
	(1) Unadjusted	(2) Adjusted
Free+Delivery vs. Cntrl	.206***	.193***
	(.039)	(.033)
Free+Delivery vs. Home Sales	.123***	.11***
	(.035)	(.03)
Free+Delivery vs. Voucher	.03	.017
	(.034)	(.031)
Controls	No	Yes
Control Mean	.561	
Obs	2356	2356

$***p < .01, **p < .05, *p < .1$
Estimates are marginal effects from a logit regression
Village Clustered SEs in parentheses
Unadjusted = Equation 1; Adjusted = Equation 2
Covariates for adjusted model described in section 7.2.4
Unit of observation=Child

Table 6: Impact On Secondary Treatment Outcomes (Last 4 Weeks)

	Zinc+ORS		Antibiotics	
	(1)	(2)	(3)	(4)
	Unadjusted	Adjusted	Unadjusted	Adjusted
Free+Delivery vs. Cntl	.329***	.308***	-.069*	-.077**
	(.056)	(.05)	(.038)	(.035)
Free+Delivery vs. Home Sales	.183***	.17***	-.049	-.048
	(.05)	(.047)	(.039)	(.035)
Free+Delivery vs. Voucher	.034	.031	.04	.031
	(.049)	(.046)	(.038)	(.035)
Controls	No	Yes	No	Yes
Control Mean	.307		.263	
Obs	2356	2356	2356	2356

$***p < .01, **p < .05, *p < .1$

Estimates are marginal effects from a logit regression

Zinc+ORS=Used both zinc and ORS to treat a case of diarrhea

Village Clustered SEs in parentheses

P-values adjusted for multiple outcomes using the free step-down resampling method

Unadjusted = Equation 1; Adjusted = Equation 2

Covariates for adjusted model described in section 7.2.4

Unit of observation=Child

Table 7: Impact On Time to ORS Use After Diarrhea Initiation

	ORS Same Day (Logit)		Days to ORS (Cox PHM)	
	(1)	(2)	(3)	(4)
	Unadjusted	Adjusted	Unadjusted	Adjusted
Free+Delivery vs. Cntl	.189***	.178***	1.653***	1.600***
	(.039)	(.036)	(.158)	(.14)
Free+Delivery vs. Home Sales	.188***	.170***	1.426***	1.349***
	(.04)	(.035)	(.119)	(.102)
Free+Delivery vs. Voucher	.075*	.070*	1.120	1.072
	(.042)	(.04)	(.095)	(.08)
Controls	No	Yes	No	Yes
Control Mean	.198		4.45	
Obs	2356	2356	2356	2356

$***p < .01, **p < .05, *p < .1$

Village Clustered SEs in parentheses

P-values adjusted for multiple outcomes using the free step-down resampling method

PHM=Proportional Hazard Model

Estimates from Cox PHM in columns 3 and 4 are hazard ratios

Unadjusted = Equation 1; Adjusted = Equation 2

Covariates for adjusted model described in section 7.2.4

Unit of observation=Child

Table 8: Impact of Free+Delivery (LATE): 2SLS

	(1) First Stage Pr(Free+Deliv)	(2) Second Stage Pr(ORS Use)	(3) First Stage Pr(Free+Deliv)	(4) Second Stage Pr(ORS Use)
Free+Delivery (Assign)	$.562^{***}$		$.546^{***}$	
	(.051)		(.049)	
Free+Delivery (Received)		$.366^{***}$		$.358^{***}$
		(.063)		(.046)
Controls	No	No	Yes	Yes
F-Stat	123.50		123.07	
Obs	1181	1181	1181	1181

$***p < .01, **p < .05, *p < .1$
Only includes Free+Delivery and Control group
Village Clustered SEs in parentheses
Covariates for adjusted model described in section 7.2.4
Unit of observation=Child
F-stat is for excluded instrument
Even columns are 2SLS estimates

Table 9: Impact of Home ORS Storage on ORS Use (LATE): 2SLS

	(1) First Stage Pr(Storage)	(2) Second Stage Pr(ORS Use)	(3) First Stage Pr(Storage)	(4) Second Stage Pr(ORS Use)
Free+Delivery	.169***		.176***	
	(.058)		(.05)	
Home Storage		.175		.133
		(.167)		(.142)
Controls	No	No	Yes	Yes
F-Stat	8.563		12.39	
Obs	1230	1230	1230	1230

$***p < .01, **p < .05, *p < .1$

Only includes Free+Delivery and Voucher groups

Village Clustered SEs in parentheses

Covariates for adjusted model described in section 7.2.4

Pr(Storage) = Probability of having ORS stored at home prior to the diarrhea episode

F-stat is for excluded instrument

Unit of observation=Child

Even columns are 2SLS estimates

Table 10: Impact of Home ORS Storage on Same-Day ORS Use (LATE): 2SLS

	(1) First Stage Pr(Storage)	(2) Second Stage Pr(ORS Same Day)	(3) First Stage Pr(Storage)	(4) Second Stage Pr(ORS Same Day)
Free+Delivery	.169***		.176***	
	(.058)		(.05)	
Home Storage		.447**		.445
		(.220)		(.210)
Controls	No	No	Yes	Yes
F-Stat	8.563		12.39	
Obs	1230	1230	1230	1230

$***p < .01, **p < .05, *p < .1$
Only includes Free+Delivery and Voucher groups
Village Clustered SEs in parentheses
Covariates for adjusted model described in section 7.2.4
Unit of observation=Child
Even columns are 2SLS estimates
Pr(Storage) = Probability of having ORS stored at home prior to the diarrhea episode
Pr(ORS Same Day) = Probability of using ORS on same day as dairrhea episode begins
F-stat is for excluded instrument
Analysis not pre-specified

Table 11: Heterogeneous Treatment Effects: Distance to Distributor

	Outcome = ORS use	
	(1)	(2)
Free+Delivery	.16***	.136***
	(.044)	(.04)
Home Sales	.075	.073*
	(.049)	(.042)
Voucher	.185***	.184***
	(.049)	(.041)
Distance (Minutes)	0	-.01
	(.02)	(.01)
Distance X Free+Delivery	.002	.004*
	(.002)	(.002)
Distance X Home Sale	0	.001
	(.003)	(.002)
Distance X Voucher	-.001	0
	(.002)	(.002)
Controls	No	Yes
Obs	2237	2237

$***p < .01, **p < .05, *p < .1$
Distance=Minutes to arrive at nearest ORS distributor
Village Clustered SEs in parentheses
Estimated using equation 5
Unit of observation=Child

Table 12: Heterogeneous Treatment Effects: Child Vulnerability

	Outcome = ORS use			
	(1)	(2)	(3)	(4)
Free+Delivery	.173***	.168***	.271***	.249***
	.042	.037	.055	.055
Home Sales	.054	.054	.108*	.105*
	(.047)	(.04)	(.06)	(.056)
Vouchers	.14***	.147***	.231***	.231***
	(.042)	(.035)	(.057)	(.056)
Age< 12 months	-1.57***	-1.38***		
	(.4)	(.47)		
Age< 12 X Free+Delivery	.125**	.099		
	(.062)	(.061)		
Age< 12 X Home Sales	.113	.119		
	(.069)	9		
Age< 12 X Vouchers	.139**	.13**		
	(.054)	(.055)		
Severe			.161***	-.037
			(.055)	(.104)
Severe X Free+Delivery			-.108	-.106
			(.072)	(.071)
Severe X Home Sales			-.048	-.036
			(.077)	(.076)
Severe X Vouchers			-.097	-.092
			(.071)	(.072)
Controls	No	Yes	No	Yes
Obs	2356	2356	2356	2356

$***p < .01, **p < .05, *p < .1$
Village Clustered SEs in parentheses
Estimated using equation 5
Unit of observation=Child
Severe=Blood in stool and/or concurrent fever

Table 13: Validating Self Report Using Packet Counting

	Counting Empty Packets				
	Pr(Empty Packet)			Self Report	
Sample	ORS=0	ORS=1	All	Pr(ORS)	Obs
Full	0.07	0.42	0.34	0.77	518
Delivery	0.13	0.51	0.47	0.88	327
Any to Show	0.20	0.63	0.57	0.87	306
Any+Delivery	0.15	0.65	0.58	0.87	262
	Fewer Packets Observed Than Obtained				
	Pr(Observed<Obtained)			Self Report	
Sample	ORS=0	ORS=1	All	Pr(ORS)	Obs
Full	0.20	0.92	0.75	0.76	505
Any to Show	0.36	0.90	0.83	0.87	306
Delivery	0.40	0.94	0.88	0.88	319
Delivery (Recode)	0.00	0.94	0.83	0.88	319

Pr(Empty Packet)=Probability at least 1 empty packet observed
Pr(Observed<Obtained)=Probability that fewer packets were observed than obtained
Sample identifies sub-group from Free+Delivery group used for estimates
Delivery=Household received free delivery
Any to Show=Household had at least 1 packet to show
Recode=Households that reported no ORS use are recoded to zero for counting measure
Analysis excludes 2 Free+Delivery villages where CHP did not participate
"ORS= 0,1" indicates whether the caretaker reported using ORS

Table 14: Placebo Tests (Health Behaviors That Should Not Be Affected)

	(1) Malaria Treatment	(2) Unclean Water/Food	(3) Bed Net	(4) Hand Washing
Free+Delivery vs. Control	-.041	-.012	.046	.016
	(.042)	(.058)	(.051)	(.049)
Free+Delivery vs. Home Sales	.012	-.066	.018	-.029
	(.041)	(.054)	(.050)	(.054)
Free+Delivery vs. Voucher	-.026	-.023	.023	.009
	(.037)	(.051)	(.048)	(.048)
Controls	Yes	Yes	Yes	Yes
Control Mean	.783	.538	.535	.718
Obs	1146	2141	2354	2363

$***p < .01, **p < .05, *p < .1$

Estimates are marginal effects from a logit regression

Village Clustered SEs in parentheses

Controls described in section 7.2.4

Malaria Treatment=child given malaria treatment in last 4 weeks (if malaria symptoms)

Unclean Water/Food=child given unclean water or food in a last 4 weeks

Bednet=child "always" slept under a bed net during last 4 weeks

Hand Washing=child washed hands at least once per day in last 4 weeks

Table 15: Impact On ORS Use (Shorter Recall Periods)

	ORS Use			
	Last 7-days		Current Case	
	(1)	(2)	(3)	(4)
Free+Delivery vs. Control	.211***	.199***	.144**	.142**
	(.043)	(.04)	(.058)	(.061)
Free+Delivery vs. Home Sales	.126**	.113**	.016	-.001
	(.037)	(.034)	(.062)	(.062)
Free+Delivery vs. Voucher	.04	.016	-.021	-.03
	(.037)	(.033)	(.057)	(.057)
Controls	No	Yes	No	Yes
Control Mean	.527		.422	
Obs	1622	1622	600	600

$***p < .01, **p < .05, *p < .1$
Estimates are marginal effects from a logit regression
Village Clustered SEs in parentheses
Controls described in section 7.2.4
7-Days implies case ended within 7 days
Current case implies case ongoing at time of survey

Table 16: Impact On ORS Use (Controlling for CHP Visits)

	Marginal Effects from Logit Regressions Outcome = ORS Use					
	(1)	(2)	(3)	(4)	(5)	(6)
Free+Delivery vs. Home Sales	.123***	.063**	.110***	.055**	.094***	.083***
	(.035)	(.032)	(.03)	(.027)	(.032)	(.028)
CHP Visit		0.247***		.234***	.234***	.224***
		(.024)		(.025)	(.025)	(.026)
Controls	No	No	Yes	Yes	No	Yes
Obs	2,356	2,356	2,356	2,356	2,282	2,282

$***p < .01, **p < .05, *p < .1$
Village Clustered SEs in parentheses
Estimates are marginal effects from a logit regression
Covariates for adjusted model described in section 7.2.4
Columns 5 and 6 exclude Home Sales households that received free ORS from CHP
Unit of observation=Child
Analysis not pre-specified

Table 17: Endline Characteristics by CHP Visit

	Free+Delivery		Home Sales	
	CHP Visit=1	CHP Visit=0	CHP Visit=1	CHP Visit=0
Number of Diarrhea Cases	357	228	188	341
Caretaker Characteristics				
Caretaker Age	31.4	28.1***	29.5	27.6
Number of Children	3.3	2.8***	3.4	2.8***
Wage Work Last 7 Days	.482	.548	.606	.625
Education				
None	.129	.101	.064	.05
Primary	.473	.43	.495	.449
Secondary+	.398	.469	.441	.501
Child Characteristics				
Child Age (Months)	25.0	22.2***	22.6	22.0
Male	.524	.575	.5	.545
Diarrhea Monthly	.216	.281	.266	.273
Blood in Stool	.067	.044	.09	.114
Concurrent Fever	.51	.518	.574	.557
Household Characteristics				
Water Source				
Piped	.14	.254***	.191	.264
Protected Well	.728	.614	.628	.551
Unprotected Source	.106	.079	.138	.123
Main Income Source				
Agriculture	.238	.167	.176	.123
Public Sector	.014	.013	.021	.029
Private Sector	.104	.14	.154	.217
Self Employed/Informal	.501	.583	.559	.548

Includes endline data for households with a case of diarrhea

Unit of observation=Child

$***p < .01, **p < .05, *p < .1$ relative to CHP visit=1

Marginal effects assessed with OLS for continuous and Logit for binary outcomes

Test for joint significance produces χ^2 with $p < .001$ for both Free+Delivery and Home Sales

Table 18: Impact on ORS and Zinc Knowledge

	(1) Control	(2) Free+Delivery	(3) Home Sales	(4) Vouchers
ORS Best Treatment	.72	.855***	.758†††	.844***
Zinc Best Treatment	.376	.665***	.514** †††	.626***
ORS+Zinc Best Treatment	.312	.639***	.459** †††	.587***
Start ORS 1st loose stool	.451	.559**	.47†	.447** ††
Give ORS after each loose stool	.307	.289	.297	.278
Start Zinc 1st loose stool	.396	.524**	.39†††	.431
Give Zinc once per day	.676	.758	.702	.692
Give Zinc for 10 days	.147	.108	.151	.153

Includes endline data for households with a case of diarrhea

Unit of observation=Child

$* * *p < .01, * * p < .05, *p < .1$ relative to control

$\dagger \dagger \dagger p < .01, \dagger \dagger p < .05, \dagger p < .1$ relative to Free+Delivery

P-values adjust for clustering at the village level

Analysis not pre-specified

Table 19: Impact On ORS Use (Controlling for Knowledge of ORS as Best Treatment)

	Marginal Effects from Logit Regressions Outcome = ORS Use			
	(1)	(2)	(3)	(4)
Free+Delivery vs. Control	.206***	.147***	.193***	.138***
	(.039)	(.037)	(.033)	(.031)
Free+Delivery vs. Home Sales	.123***	.081**	.11***	.067**
	(.035)	(.032)	(.03)	(.027)
Free+Delivery vs. Vouchers	.03	.027	.017	.011
	(.034)	(.03)	(.031)	(.027)
ORS Best Treatment		.438***		.426***
		(.034)		(.033)
Controls	No	No	Yes	Yes
Obs	2356	2355	2356	2355

$***p < .01, **p < .05, *p < .1$
Estimates are marginal effects from a logit regression
Village Clustered SEs in parentheses
Covariates for adjusted model described in section 7.2.4
Unit of observation=Child
Analysis not pre-specified

Table 20: Take-up, Use, and Unused ORS

	Only Households With Case of Diarrhea			
	Control	Free+Delivery	Home Sales	Vouchers
Coverage	.561	$.767^{***}$	$.644^{**}_{\dagger\dagger\dagger}$	$.737^{***}$
Take-Up	.567	$.826^{***}$	$.645^{*}_{\dagger\dagger\dagger}$	$.772^{***}$
Take-Up (CHP)	.115	$.648^{***}$	$.25^{***}_{\dagger\dagger\dagger}$	$.553^{***}$
Compliance	.9	.894	$.938_{\dagger}$	.922
Compliance (CHP)	.884	.892	$.955_{\dagger}$	.919
	All Households			
	Control	Free+Delivery	Home Sales	Vouchers
Coverage	.172	.211	.18	$.214^{**}$
Take-Up	.247	$.701^{***}$	$.372^{***}_{\dagger\dagger\dagger}$	$.543^{***}_{\dagger\dagger\dagger}$
Take-Up (CHP)	.071	$.634^{***}$	$.211^{***}_{\dagger\dagger\dagger}$	$.457^{***}_{\dagger\dagger\dagger}$
Compliance	.639	$.29^{***}$	$.455^{***}_{\dagger\dagger\dagger}$	$.381^{***}_{\dagger\dagger\dagger}$
Compliance (CHP)	.445	$.251^{***}$	$.316^{*}$	$.324^{*}_{\dagger\dagger}$

Unit of observation=Child

$***p < .01, **p < .05, *p < .1$ relative to control

$\dagger\dagger\dagger p < .01, \dagger\dagger p < .05, \dagger p < .1$ relative to Free+Delivery

P-values adjust for clustering at the village level

Coverage = 1 if used ORS in last 4 weeks

Take-Up = 1 if obtained ORS from any source in last 4 weeks

Take-Up (CHP) = 1 if obtained ORS from CHP in last 4 weeks

71% redeemed vouchers of those that received vouchers

Take-Up (CHP) = 1 if obtained ORS from CHP in last 4 weeks

Compliance = Pr(Use|Take-Up)

Compliance (CHP) = Pr(Use|Take-Up (CHP))

Table 21: Difference in Unused ORS Packets

	Unused ORS Packets: OLS	
	Sample Used For Estimates	
	Case Of Diarrhea	All Households
Free+Delivery vs. Control	.71***	1.44***
	(.14)	(.164)
Free+Delivery vs. Home Sales	.73***	1.16***
	(.146)	(.182)
Free+Delivery vs. Vouchers	.11	.44***
	(.174)	(.213)
Control Mean	.33	.31
Obs	2361	8176

$***p < .01, **p < .05, *p < .1$
Village Clustered SEs in parentheses
Unit of observation=Household
Case of Diarrhea = Includes only households with a case of diarrhea
Analysis not pre-specified

Table 22: Cost-Effectiveness Analysis Inputs

Input	Base Value	Lower	Upper	Source
Population Size	1,939	N/A	N/A	Study Data
Diarrhea Prevalence	.31	.29	.33	Study Data
Cases Per Year	5	8	2	Study Data
Pr(Death|Diarrhea)	.0014	0.0007	0.0026	Liu et al. (2015)
ORS Effectiveness (RRR)	0.93	.69	1	Munos et al. (2010)
Eff Free+Delivery (% point)	0.21	0.13	0.28	Study Data
Eff Home Sales (% point)	0.08	0.0005	0.17	Study Data
Eff Vouchers (% point)	0.18	0.10	0.26	Study Data
Hourly Wage (UG Women)(USD)	0.28	0.25	0.30	LSMS in 2011/2012
ORS Costs Per HH (USD)				
Control	<0.01	<0.01	0.01	Study Data
Free+Delivery	0.14	0.12	0.17	Study Data
Home Sales	0.04	0.03	0.05	Study Data
Vouchers	0.11	0.09	0.13	Study Data
Time Costs Per HH (USD)				
Control	0.17	0.13	0.20	Study Data
Free+Delivery	0.07	0.06	0.09	Study Data
Home Sales	0.15	0.12	0.18	Study Data
Vouchers	0.14	0.11	0.17	Study Data
Treatment Costs Per HH (USD)				
Control	0.65	0.54	0.76	Study Data
Free+Delivery	0.27	0.20	0.34	Study Data
Home Sales	0.56	0.45	0.67	Study Data
Vouchers	0.41	0.31	0.51	Study Data
Clinic Costs Per HH (USD)				
Control	0.35	0.28	0.43	Study Data
Free+Delivery	0.16	0.10	0.21	Study Data
Home Sales	0.35	0.26	0.44	Study Data
Vouchers	0.21	0.15	0.26	Study Data
Transport Costs Per HH (USD)				
Control	0.04	0.03	0.05	Study Data
Free+Delivery	0.03	0.02	0.04	Study Data
Home Sales	0.04	0.03	0.05	Study Data
Vouchers	0.03	0.02	0.04	Study Data

Study data uses 95% confidence intervals to create lower and upper bounds

Table 23: Itemized Cost Estimates

	Monthly Costs For 30 Villages (USD)			
Item	Control	Free+Delivery	Home Sales	Vouchers
Brac Costs (ORS)	9.22	280.64	84.29	216.77
Household Costs	2,008.66	855.48	1,804.00	1,203.84
Time	322.59	143.56	292.82	269.49
Treatment	1,265.91	522.12	1,083.29	802.44
Clinic	685.57	301.00	680.20	402.63
Transport	85.49	59.56	75.33	59.21
Total Costs	2,017.88	1,136.12	1,888.29	1,420.61

BRAC cost = cost of the ORS obtained by caretakers from CHPs
Time costs = reported time seeking treatment X hourly wage
Treatment costs = reported amount spent on treatment
Clinic costs = reported amount spent on clinic/doctor fees
Transport costs = reported amount spent on transport
30 Villages = 1,936 Households

Table 24: Incremental Costs by Perspective

	Implementor Perspective	
	Costs	Inc. Cost
Control	9.22	.
Home Sales	84.29	75.07
Vouchers	216.77	132.48
Free+Delivery	280.64	63.87
	Societal Perspective	
	Costs	Inc. Cost
Free+Delivery	1,136.12	.
Vouchers	1,420.61	284.49
Home Sales	1,888.29	476.68
Control	2,017.88	129.59

Implementor perspective includes only ORS costs
Societal perspective includes ORS cost and household costs
Inc. Cost= incremental cost relative to next most expensive alternative

Table 25: Incremental Benefits And ICERs (Implementor Perspective)

	Cases Treated	Incremental Treated	ICER Cost Per Case Treated	Deaths	DALYs Averted	ICER Cost Per DALY Averted
			Compared to Next Best Alternative			
Control	337	.	.	0.39	.	.
Home Sales	386	50	$1.51	0.32	1.70	$44
Voucher	442	56	$2.37	0.25	1.92	$69
Free+Delivery	460	18	$3.56	0.23	0.61	$104
			Free+Delivery Compared to Other 2 Groups			
FD vs. Cntrl	.	124	$2.20	.	4.24	$64
FD vs. HS	.	74	$2.66	.	2.53	$77

Costs include only ORS costs from Table 23, Row 1
ICERs are relative to next most effective alternative aside from last 2 rows
DALYs averted assumes each death = 27.15 Years of Life Lost with 3% discounting

Table 26: One-Way Sensitivity Analysis (ICERs)

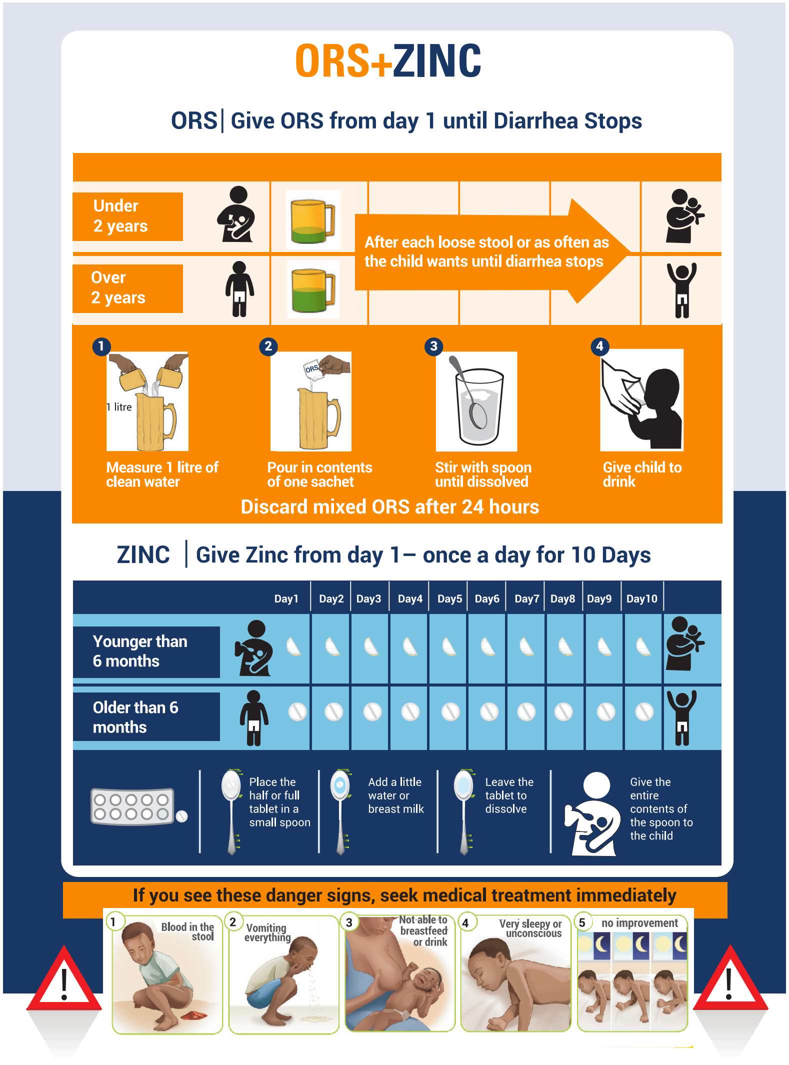
	ICER Upper Bound			ICER Lower Bound		
	Treated	DALYs	Parameter	Treated	DALYs	Parameter
Sale v Cntl	259.46	7,566	Eff Sales LB	.76	22.09	Eff Sales UB
Vouch v Sale	20.08	586	Eff Sales UB	2	35.91	Pr(Death) UB
Deliv v Vouch	3.56	189	Pr(Death) LB	Dom	Dom	Eff Deliv LB
Deliv vs. Sale	8.01	234	Eff Sales UB	2.65	40	Pr(Death) UB
Deliv vs. Cntrl	3.49	117	Pr(Death) LB	1.60	33	Pr(Death) UB

Estimate are from 16 separate analyses per ICER each using upper or lower bounds of parameters from Table 22
Parameter=the parameter that led the upper/lower bound
Dom=dominated by reference
Treated=Cases Treated
Eff=Effectiveness
LB/UB=Parameter set to lower bound/upper bound

15 Appendix

15.1 Appendix Figures

Figure A1. Flyer used to provide ORS and zinc knowledge to caretakers



15.2 Appendix Tables

Table A1. Outcomes by CHP visit

	CHP Visit=1				CHP Visit=0			
	CNTRL	FD	HS	Vouch	CNTRL	FD	HS	Vouch
Exposure to Treatments								
Free ORS Delivery	.106	.835	.282	.306	.013	.228	.012	.069
Home Sales Offer	.303	.188	.388	.234	.026	.022	.05	.031
Received Voucher	.085	.081	.064	.685	.004	.057	.003	.166
Take-Up and Storage								
Obtained ORS from CHP	.359	.908	.606	.841	.039	.241	.053	.197
Obtained Zinc from CHP	.31	.916	.527	.797	.044	.241	.05	.193
ORS Stored: Currently	.232	.566	.287	.518	.1	.241	.141	.221
ORS Stored: Diarrhea	.141	.692	.255	.468	.068	.207	.103	.166
Zinc Stored: Currently	.218	.714	.351	.607	.105	.259	.161	.279
Zinc Stored: Diarrhea	.106	.669	.207	.451	.057	.185	.059	.135
Use of ORS and Zinc								
Used ORS	.676	.874	.818	.855	.525	.601	.548	.59
Used Zinc	.577	.823	.717	.808	.312	.43	.411	.448
Used ORS+Zinc	.465	.798	.674	.777	.257	.382	.331	.382
Knowledge								
ORS Best Treatment	.824	.902	.83	.9	.687	.781	.718	.776
Zinc Best Treatment	.606	.801	.665	.802	.304	.452	.431	.407
ORS+Zinc Best Treatment	.507	.779	.628	.763	.252	.421	.367	.369
Start ORS immediately	.422	.542	.51	.456	.464	.592	.442	.433
Give ORS after each stool	.333	.279	.345	.27	.296	.309	.264	.292
Start Zinc immediately	.372	.497	.36	.458	.41	.602	.415	.364
Give Zinc once per day	.651	.783	.696	.684	.691	.689	.707	.712
Give Zinc 10 days	.081	.105	.112	.156	.187	.117	.184	.144

CNTL=Control Group; FD=Free+Delivery; HS=Home Sales; Vouch=Vouchers

Table A2. Mechanisms of Free+Delivery Intervention Relative to Control (ORS Use)

	(1)	(2)	(3)	(4)	(5)
Assignment to Free+Delivery	0.206***	0.0164	0.124***	0.0307	-0.00920
	(0.0388)	(0.0344)	(0.0349)	(0.0420)	(0.0439)
Obtained ORS From CHP		0.357***			
		(0.0394)			
Visit from CHP			0.219***	0.134***	0.0915**
			(0.0344)	(0.0375)	(0.0379)
Free Delivery from CHP				0.223***	0.0924*
				(0.0530)	(0.0486)
ORS Stored Prior to Diarrhea					0.308***
					(0.0333)
N	1181	1181	1181	1181	1180

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Table A3. Mechanisms of Voucher Intervention Relative to Control (ORS Use)

	(1)	(2)	(3)	(4)	(5)	(6)
Assignment to Vouchers	0.176***	0.00183	0.107***	0.0766*	0.0616	0.0350
	(0.0406)	(0.0385)	(0.0388)	(0.0447)	(0.0447)	(0.0438)
Obtained ORS from CHP		0.397***				
		(0.0348)				
Visit from CHP			0.219***	0.187***	0.162***	0.135***
			(0.0336)	(0.0361)	(0.0351)	(0.0350)
Received Voucher				0.0936*	0.0935**	0.0705
				(0.0475)	(0.0465)	(0.0451)
Free Delivery From CHP					0.137***	0.0714**
					(0.0334)	(0.0332)
ORS Store Prior to Diarrhea						0.226***
						(0.0257)
N	1244	1244	1244	1244	1244	1244

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Table A4. Mechanisms of Home Sales Intervention Relative to Control (ORS Use)

	(1)	(2)	(3)	(4)	(5)	(6)
Assignment to Home Sales	0.0828*	0.0296	0.0580	0.0499	0.0407	0.0277
	(0.0417)	(0.0333)	(0.0373)	(0.0368)	(0.0356)	(0.0325)
Obtained ORS from CHP		0.395***				
		(0.0309)				
Visit from CHP			0.214***	0.155***	0.122***	0.107**
			(0.0374)	(0.0395)	(0.0399)	(0.0404)
Home Sales Offer from CHP				0.191***	0.184***	0.157***
				(0.0410)	(0.0398)	(0.0404)
Free Delivery from CHP					0.186***	0.131**
					(0.0522)	(0.0512)
ORS Stored Prior to Diarrhea						0.291***
						(0.0370)
N	1125	1125	1125	1125	1125	1125

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Table A5. Determinants of ORS Use in the Control Group

	Outcome=ORS (1)
Caretaker Characteristics	
Caretaker Age	0.00179
	(0.00244)
Number of Children	0.00174
	(0.0181)
Number of Children Under-5	0.00894
	(0.0323)
Worked last 7-days	0.135***
	(0.0432)
Education: Relative to None	
Primary	-0.0321
	(0.0788)
Secondary+	0.0475
	(0.0826)
Child Characteristics	
Child is Male	-0.00123
	(0.0397)
Child Age	0.00282**
	(0.00143)
Diarrhea each month	0.0501
	(0.0436)
Blood in stool	0.0804
	(0.0795)
Concurrent fever	0.169***
	(0.0405)
Households Characteristics	
Water Source: Relative to Unprotected	
Piped	0.146*
	(0.0785)
Protected Well	0.196***
	(0.0605)
Income: Relative to Private Sector	
Agriculture	0.0730
	(0.0676)
Public Sector	-0.0363
	(0.178)
Self-Employed	0.087
	(0.0527)
N	597

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Table A6. Full Regression Result from Primary Analysis in Table 5

	(1) Marginal Effects
Treatment Effects: Relative to Control	
Free+Delivery	0.193***
	(0.0334)
Home Sales	0.0837**
	(0.0342)
Vouchers	0.176***
	(0.0339)
Caretaker Characteristics	
Age	0.00275**
	(0.00133)
Number of Children	0.00917
	(0.00770)
Education: Relative to None	
Primary	-0.00104
	(0.0425)
Secondary+	0.0453
	(0.0403)
Child Characteristics	
Age	0.000798
	(0.000665)
Diarrhea Frequency: Relative to Monthly	
Every 2 months	0.0222
	(0.0285)
Every 3 months	0.0214
	(0.0291)
Every 4 months	0.0279
	(0.0308)
Less than every 4 months	0.0369
	(0.0257)
Blood in Stool	0.0424
	(0.0362)
Concurrent Fever	0.0959***
	(0.0227)
Households Characteristics	
Water Source: Relative to Piped	
Protected Well	0.0521*
	(0.0300)
Unprotected Source	-0.0540
	(0.0391)
Main Source Of Income: Relative to Agriculture	
Public Sector	0.0160
	(0.0591)
Private Sector	-0.0288
	(0.0338)
Informal	0.00174
	(0.0250)

Latrine Type: Relative to Covered	
Uncovered	-0.0414*
	(0.0212)
Bush	-0.218
	(0.0981)
Village Characteristics (Baseline)	
% Visited by CHP Last 4-Weeks	0.0917**
	(0.0419)
% Aware of Free ORS in Village	-0.0769*
	(0.0462)
% With ORS Stored in Home	0.0237
	(0.0791)
% Used ORS	-0.00450
	(0.0643)
Observations	2,356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1