“Impact Evaluation of a Diarrhea Treatment Uptake Scale-up Program in Nigeria - a Difference-in-Difference Analysis”

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1. Introduction

1.1: Background:

Globally, diarrheal disease remains one of the leading causes of death in children under 5 years with 1.7 billion cases of childhood diarrhea annually (1,2). The highest burden is concentrated in the Sub-Saharan Africa and South Asia regions (3). Specifically, diarrheal disease is the second leading cause of death in children under 5 years old in Nigeria with an estimated 151,700 children that die annually from diarrheal disease (4,5). Recent trends in Nigeria also indicate child diarrheal prevalence at 13% in 2021 with only 65.2% of children under 5 years old with diarrheal disease seeking treatment or advice (6).

Despite the high burden of disease, key measures can be taken to effectively treat diarrheal disease. Oral Rehydration Salts (ORS) solutions prevent 93% of diarrheal deaths and are taken to replace the loss of water and electrolytes during diarrheal episodes (2). Zinc supplements can reduce stool volume and the duration of diarrheal episodes which can reduce the risk of malnutrition (2). Though diarrheal disease is very treatable, the lack of access to treatment is an important determinant of the high mortality from diarrheal disease. Evidently, as of 2021, only 65.2% of children in Nigeria with diarrhea sought treatment or advice (6).

1.2 Program Description:

Driven to reduce morbidity and mortality rates due to childhood diarrhea, the Federal Ministry of Health (FMoH) and National Primary Health Care Development Agency (NPHCDA) launched the Essential Medicines Scale-Up Plan (2012-2015), a concrete roadmap to reduce child mortality by increasing treatment and reaching 80% coverage of appropriate treatment (including ORS and zinc) for diarrheal disease (7). In 2013, with funding from the Norwegian Agency for Development Cooperation (Norad) and Global Affairs Canada (GAC), the Clinton Health Access Initiative (CHAI) worked with the Nigeria government to implement the aims outlined in the Essential Medicines Scale-Up Plan. Through targeting children under 5 years with diarrheal disease in eight high-burden states Bauchi, Cross River, Kaduna, Kano, Katsina, Lagos, Niger, and Rivers, an ORS and zinc scale-up program aimed to build demand, ensure widespread availability, reduce costs of ORS and zinc supplements in hard-to-reach areas to increase treatment-seeking behavior (8).

The zinc and ORS scale-up program implemented by CHAI focused on several core objectives when conducting the intervention from 2013-2017: (1) creating an enabling environment via mobilizing resources for implementation (2) ensuring widespread availability and affordability of optimal zinc/ORS products and (3) building health provider and caregiver demand (8). To create an enabling environment, the ORS and Zinc Scale-Up program collaborated with FMoH, NPHCDA, and state ministries of health (SMoH) to build support, align key stakeholders, mobilize resources for implementation, and establish coordination at state and national levels (8). In order to coordinate implementation, the FMoH and NPHCDA formed the National Essential Medicines Coordination Mechanism (NEMCM), a partnership consisting of the Nigerian government and over 15 partners (8). To ensure widespread availability and affordability of optimal zinc/ORS products, the ORS and Zinc Scale-Up program collaborated with local manufacturers to facilitate the production, marketing, and sale of optimal zinc and ORS products with a focus on increasing reach to rural areas. Specifically, zinc dispersible tablets, the WHO-recommended low-osmolarity (Lo-ORS) formulation, and co-packaged zinc and ORS were promoted in the Nigerian market (9). The program also worked with local suppliers to reduce the wholesale price of zinc/ORS packets to promote affordability. To build health provider and caregiver demand, the program collaborated with SMoHs, professional associations, the National Association of Patent and Proprietary Medicines (NAPPMED), and the Pharmacists Council of Nigeria (PCN) to reach public and private providers and strengthen existing platforms (8).To promote care-seeking behavior among consumers, the program developed resources and messaging systems to promote zinc/ORS products to communities and organized education campaigns for caregivers (mostly mothers) on appropriate diarrheal care through health talks, Islamiyah schools, and women's groups. In Bauchi, Kaduna, Kano, Katsina, and Rivers, radio campaigns were also implemented. By the end of 2016, the NEMCM mobilized over 50 million USD for program implementation. At the end of the program, they were able to reach 24,000 public providers in primary health centers and secondary health facilities and nearly 32,000 individual PPMVs (8). In terms of accessibility and affordability of zinc/ORS packets, more than 15 new zinc and Lo-ORS products (including co-pack) were introduced to the local market with a 70% drop in wholesale price (8). Lastly, the program reported that combined zinc and ORS coverage increased from 3% to 31% across all eight states (8).

1.3 Study Objectives:

Previous studies have explored the determinants of zinc and ORS uptake as well as evidence in support of interventions that are tailored to scale-up access to zinc and ORS treatment (9-11). Several studies have assessed the efficacy of the zinc and ORS program regarding child diarrheal disease in Nigeria and have found a statistically significant increase in zinc and ORS coverage at the end of the intervention program compared to the start of the intervention program with a specific pro-rural coverage increase (9-11). Such studies will be explored to a fuller extent in the literature review. Despite the research that has been done in assessing determinants of diarrheal treatment uptake and assessing the efficacy of the zinc and ORS scale-up program, there remain gaps in the literature for rigorous analysis assessing the causal impact of the program on zinc and ORS treatment uptake.

Given the reported increase in zinc and ORS coverage across the targeted eight states after the intervention was applied, it is important to evaluate these claims through a rigorous causal framework to assess whether the increased availability of diarrhea treatment led to an increase in treatment-seeking behavior among children under five years with diarrheal disease. Additionally, the study will evaluate whether a one-size-fits-all policy solution exists in scaling up diarrheal treatment by specifically evaluating impact based on geographical region and socioeconomic status. Though the program took place from 2012-2017, there is an existing significant childhood diarrheal disease burden, and insights from this study will be useful in guiding policymaker decisions related to childhood diarrheal prevention and treatment in Nigeria.

Thus, in this thesis, I will conduct a difference-in-difference analysis (DiD) to assess the causal impact of the zinc and ORS scale-up program intervention on diarrhea treatment uptake of children under five years with diarrheal disease in the eight states that implemented the program compared to control states that did not receive the program. Additional subgroup analyses will examine whether specific groups by rural/urban or wealth quintile breakdown were impacted by the program.

Literature Review:

2.1 Rationale:

Despite the significant burden of child diarrheal disease in Nigeria, diarrheal disease is very treatable. The World Health Organization (WHO) recommends lo-ORS along with a 10-14 day supplemental treatment course of dispersible zinc tablets (World Health Organization, 2024). Previous studies have supported this recommendation that zinc supplementation shortens the average duration of diarrheal disease and ORS can replace loss of water and electrolytes (Lazzerini et.al, 2016; Patel et.al, 2010; Pierce et.al, 1969; Guarino et.al, 2012). Specifically, studies have found that lo-ORS presents as the optimal type of ORS compared to alternative ORS solutions such as sorghum or glycine (Pelleboer, 1990; Grange, 1992). The implications of existing literature supporting zinc and ORS treatment is twofold: there is evidence supporting zinc supplementation and lo-ORS for treating diarrheal disease and it is thus necessary in focusing efforts on scaling up zinc and ORS treatment.

Given the importance of diarrheal treatment uptake in reducing child diarrheal disease mortality, it is important to conduct a preliminary literature review to understand past efforts that have been made to scale-up zinc and ORS treatment in the sub-Saharan Africa region.

To conduct the literature review, I included keyword searches such as “Policy”, “Intervention”, “Oral Rehydration Salt”, “Oral Rehydration Solution”, “zinc”, “ORS”, “diarrheal disease”, “diarrhea”, and “Nigeria.” Such keywords centered the literature review around understanding the diarrheal treatment-seeking landscape for child diarrheal disease in Nigeria and to answer the research question: What is the effect of the zinc and ORS scale up program implemented by Clinton Health Access Initiative (CHAI) on zinc and ORS treatment uptake for children under five years with diarrheal disease in the targeted eight high-burden disease states compared to children under five years in the states that did not receive the zinc and ORS scale up program?

. Specifically, the literature review is centered around examining determinants of diarrheal disease treatment uptake and policies that have aimed to scale-up zinc and ORS in the sub-Saharan Africa region. The literature review will also evaluate level of rigor in methods of previous studies that have assessed the impact of the zinc and ORS scale-up program implemented by CHAI.

2.2 Determinants of zinc and ORS uptake:

Previous literature assessed determinants of zinc and ORS uptake through quantitative methods such as observational studies or through qualitative methods such as interviewing caregivers and healthcare providers (22-27**)**. Specifically, the literature grouped determinants of zinc and ORS uptake on several levels: individual, caregiver, household, and community-level characteristics.

On an individual level, researchers evaluated characteristics of children under five years with diarrheal disease and assessed its impact on zinc and ORS uptake in Nigeria. Studies have found that child age, child size at birth (first year of life), and whether the child was born in a facility was associated with zinc and ORS uptake (22,23,25). Specifically, children who were younger were less likely to receive ORS and children who were average size at birth were more likely to receive ORS compared to their counterparts who were larger than average size at birth (22,23). Additionally, children who were born in a facility were more likely to receive zinc and ORS treatment compared to children who were born in a non-institutional setting (22). The implications is that when the impact of the zinc and ORS scale-up program is evaluated, the characteristics of the child under five years could inherently impact treatment uptake outcomes.

On a caregiver level, studies included caregiver characteristics in general or specifically characteristics of the mother and assessed its impact on child zinc and ORS uptake. Across studies included in the literature review, caregiver awareness of diarrheal disease management and knowledge on preparation of ORS were determinants that impacted zinc and ORS treatment uptake. Studies found that caregivers often use alternative forms of treatment such as salt-sugar solution (SSS), antibiotics, anti-diarrheal disease, or herbal medication to treat child diarrheal disease rather than the standard lo-ORS and zinc supplementation (24,26,27). Specifically, the breakdown of caregiver management of child diarrheal disease includes 64.6% of caregivers utilizing ORS, 52.1% antibiotics, 27.2% SSS, 18.6% anti-diarrhoeal drugs, and only 12.9% of caregivers administering oral zinc (24). The disparities in caregiver usage of ORS and zinc are particularly salient as SSS lacks key potassium that will need to be replenished during dehydration, and antibiotics will not appropriately address viral causes of diarrheal disease (28).

Such disparities in caregiver usage of ORS and zinc were rooted in a lack of awareness of ORS and zinc supplementation in Nigeria. Specifically, studies have reported that though 85.5% of mothers were aware of ORS, only 22.1% of them prepared it correctly and 39.4% of mothers could correctly manage diarrhea at home (31). Additional studies have reported that only 53.3% of mothers were aware of zinc supplementation (25). As outlined in the literature review below, many policies and interventions have targeted caregiver awareness of zinc and ORS treatment and proper administration to increase diarrheal treatment uptake among children under five years. Similarly, the zinc and ORS scale-up program implemented by CHAI directly targets caregiver awareness by encouraging caregivers to seek treatment and providing resources on proper ORS and zinc usage via radio campaigns or messaging through community leaders.

In terms of additional caregiver characteristics, studies have found caregiver sex, education level, employment status, and religious/ethnic groups as determinants of zinc and ORS treatment uptake among children under five years (22,23,25). As a result, caregiver characteristics can impact zinc and ORS treatment uptake during program implementation and must be controlled for in subsequent analyses.

At a household level, studies have found that type of residence, wealth quintile, and source of drinking water were determinants of zinc and ORS treatment uptake among children under five years in Nigeria. Across studies, urban children had higher zinc and ORS treatment uptake compared to rural children, higher wealth quintiles had higher zinc and ORS treatment uptake compared to lower wealth quintiles, and children with improved sources of drinking water had higher zinc and ORS treatment uptake compared to children without improved sources of drinking water (22,25). This is particularly salient as zinc and ORS treatment have marked wealth and geographic disparities that must be controlled for when assessing zinc and ORS program impact. Additionally, because of existing disparities, zinc and ORS program impact may disproportionately benefit wealthier groups or rural versus urban regions.

Lastly, at a community level, the literature specifically explores sources of care that are available within a community. In particular, Patent and Proprietary Medicine Vendors (PPMVs) are increasingly becoming an integral part of healthcare service delivery in Nigeria with over 200,000 shops in Nigeria (29). PPMVs are vendors without formal pharmacy training who sell pharmaceutical products for profit and are cited as the main source of medicine for many common childhood illnesses due to consistency in service delivery (no service interruptions), long hours, and presence in hard-to-reach areas (30). The implications is that PPMVs play a crucial role in delivery for zinc and ORS treatment for child diarrheal disease.

Studies specifically characterized zinc and ORS access in the context of PPMV shops and analyzed regional disparities, treatments offered, and PPMV awareness of zinc and ORS treatment. A consistent trend was observed across studies in higher ORS stocking than zinc supplementation with one study in particular noting 92.1% of shops that stocked oral rehydration salts but only 19.1% carried zinc (29,32). Combined with overall increased ORS usage compared to zinc usage by caregivers, this is particularly salient as there is an observed disparity between zinc and ORS uptake for children with diarrheal disease.

Characteristics of PPMVs such as receiving medical training or health training background were strong indicators of awareness and stocking patterns for zinc and ORS treatments in shops (29,30,32). Access to PPMVs with formal training was dependent on regional differences with 52.6% of PPMVs with medical training in northern regions compared to only 29.7% in southern states (32). PPMV access is particularly salient as it not only directly provides a source of diarrheal treatment to caregivers, but it also is an important component of the zinc and ORS scale up program. Specifically, the program partnered with the National Association of Proprietary Patent Medicine Vendors (NAPPMED) and Pharmacists Council of Nigeria to provide state-level trainings to approximately 19,000 PPMVs on appropriate zinc and ORS practices for diarrheal disease management (9). The implications is that PPMVs are an important area to target when increasing awareness on zinc and ORS treatment and scaling up zinc and ORS access.

In terms of geographic disparities as a whole, the regional disparity in trained PPMVs was further reinforced by a regional access disparity in treatment access. Specifically, studies have found that ORS coverage is lower in North Nigeria compared to the South and diarrheal disease burden and prevalence is highest in the Northern region (22,33). Consequently, policies and interventions can specifically target areas of high burden of diarrheal disease and low access to zinc and ORS treatment.

Although this thesis is focused on evaluating the impact of the scale-up program on zinc and ORS uptake, the causal impact cannot be assessed without controlling for other determinants that impact zinc and ORS uptake. In categorizing determinants of diarrheal treatment uptake into individual, caregiver/household, and community level determinants, the literature provides critical information on what variables to specifically control for and how the variables can be grouped into distinct levels when assessing causal impact.

2.3 Policies and Programs

The zinc and ORS scale-up program implemented by CHAI is one of many programs implemented in Nigeria with aims to increase zinc and ORS treatment uptake. It is crucial to outline additional policies or programs that target increasing zinc and ORS uptake or determinants of zinc and ORS uptake to better understand what programs have been successful/what have not worked.

Past efforts to increase zinc and ORS uptake have targeted caregiver awareness. For instance, a randomized control trial conducted in Ilorin, Nigeria, assessed the efficacy of mobile phone call reminders/texts for caregivers to promote zinc and ORS treatment adherence for children under five years (34). Researchers found that compared to the control group that did not receive any phone call or text reminders, there was 1.6 times and 1.7 times increased adherence to ORS and zinc treatment, respectively (34). The implication is that rigorous methods were used via randomization of the intervention to thoroughly assess the impact of the program.

Additionally, programs have integrated zinc and ORS educational resources to improve caregiver awareness. Maternal Newborn Child Health Week (MNCHW)in Nigeria are week-long events aimed to deliver cost-effective services and interventions through partnerships with communities. Researchers aimed to assess the efficacy of promoting zinc tablets and ORS during MNCHW on improving caregiver knowledge on diarrheal case management for children under five years. On-site counseling and a take-home kit for proper diarrheal management were integrated into the November 2010 MNCHW and May 2011 MNCHW, and researchers interviewed caregivers the day before and after each MNCHW (35). Researchers ultimately found that the proportion of caregivers with knowledge of the treatment for diarrhea increased from 46.4% in November 2010 pre-MNCHW to 71.3% in May 2011 post-MNCHW interviews and caregivers' knowledge of the treatment of diarrhea increased seven times compared to the caregivers who attended the May 2011 MNCHW (35). Because researchers used a before and after analysis, a control group was not utilized, and determinants of diarrheal treatment uptake were not controlled for.

Intervention programs have also targeted caregiver awareness in a healthcare setting. In particular, researchers have implemented a randomized control trial the efficacy of Oral Rehydration Therapy (ORT) corners on improving caregiver knowledge and skill regarding at-home diarrheal disease management for children under five years. ORT corners were implemented in select health facilities in Bauchi and Sokoto state and caregivers received practical demonstrations and diarrhea home case management training. Researchers found that caregivers that utilized ORT corners were more knowledgeable in diarrhea prevention and management compared to non-ORT corner users (36).

Lastly, on a larger scale, the Nigeria Ministry of Health adopted the Integrated Community Case Management (iCCM)strategy to scale up diagnostic, treatment, and referral services for common childhood illnesses such as malaria, pneumonia, and diarrhea in Abia and Niger state from 2013-2017(21). Specifically, the iCCM strategy is based on training community healthcare workers (CHWs) to appropriately assess, diagnose, and treat children under five years with the three common childhood illnesses outlined above (21). Researchers estimated 1,400 deaths and 1,280 deaths were prevented by pneumonia, diarrhea, and malaria treatment interventions in children under five years of age throughout the intervention period in Abia state and Niger state, respectively (21). Because the iCCM strategy was implemented during the zinc and ORS scale-up program and the zinc and ORS scale-up program also targeted Niger, iCCM program impact must be excluded when assessing the zinc and ORS scale-up program impact.

Overall, interventions targeted caregiver awareness and healthcare provider training/knowledge to increase zinc and ORS uptake, which aligns with the zinc and ORS scale-up program's strategy in training PPMVs and increasing caregiver awareness and demand. However, there have been limited programs that targeted zinc and ORS treatment uptake and have utilized rigorous analyses to assess program impact.

2.4 Previous Studies on the zinc and ORS scale-up program implemented by CHAI

Previous studies have evaluated the efficacy of the zinc and ORS scale-up program implemented by CHAI on zinc and ORS treatment uptake among children under five years with attributed to the zinc and ORS scale-up program.

First, a study that specifically observed the impact of the zinc and ORS scale-up program on zinc and ORS treatment uptake in the eight targeted states (Bauchi, Cross River, Kaduna, Kano, Katsina, Lagos, Niger, and Rivers) found that the odds of diarrhea being treated with ORS were

1.88 times greater post-intervention and the odds of diarrhea being treated with both zinc and ORS was 15.14 times greater post-intervention (9). The study sought to assess program impact via five outcomes: 1) change in care-seeking for children with diarrheal disease; 2) change in treatment seeking with ORS for children with diarrhea 3) the change in treatment seeking for zinc and ORS for children with diarrhea 4) whether the change over time in treatment with ORS was modified by the source of care (i.e., home, public sector, private sector, other sector, or multiple sectors); and 5) whether the change over time in treatment with combined ORS and zinc was modified by the source of care (9). Researchers utilized baseline (2013-2014), midline (2015), and endline (2016-2017) household surveys within the eight treatment states to collect data on the five outcomes. Finally, to assess impact, researchers ran a logistic regression on each outcome and controlled for potential confounders, including child, caregiver, and household-level characteristics (9).

Because the study only compares before and after outcomes within targeted intervention states, the study lacks a control group to compare care-seeking outcomes to. Without a control group that considers zinc and ORS treatment uptake of children under five years who were not exposed to the intervention, researchers cannot conclude that improved zinc and ORS treatment uptake is attributed to the zinc and ORS scale-up program. Consequently, the study cannot claim a causal impact between the program and outcomes.

In a follow-up study that assessed changes in the inequities of coverage of ORS and zinc throughout the program implementation, researchers found pro-rural improvement in diarrheal treatment coverage and a reduction in coverage inequities across wealth quintiles before and after program implementation (10). Researchers utilized the same baseline, midline, and endline household surveys outlined above and assessed three outcomes: (1) changes in zinc treatment seeking among children with diarrheal disease (2) changes in ORS treatment seeking among children with diarrheal disease and (3) changes in zinc and ORS treatment seeking among children with diarrheal disease. Researchers ran a multi-level, mixed-effects logistic regression on subgroups by wealth quintiles or type of residence (urban or rural) and included population characteristics as potential confounders. Summary measures of inequality were measured via absolute and relative disparities.

Ultimately, in terms of socioeconomic status, researchers found that the ORS coverage increase from baseline to endline was higher for the poorest, with disparity gaps narrowed after the program ended (10). Absolute and relative disparities were different for zinc coverage as absolute disparities for zinc uptake between the highest and lowest wealth quintile were higher (11%) at endline relative to baseline absolute disparities(7%), favoring the richest quintile (10). On the other hand, the ratio of richest/poorest for the relative disparity for zinc decreased from 3.5:1 to 1.3:1 from baseline to endline (10). In terms of type of residence (urban or rural), ORS and zinc coverage had absolute and relative disparities that favored urban areas initially and favored rural regions at the endline surveys (10). Consequently, researchers concluded a pro-rural coverage and reduction in wealth disparities due to the zinc and ORS scale-up program.

Because this study uses a similar methodology to the previous study, there is a lack of rigor in methods due to the lack of a control group to compare as a reference group in terms of zinc and ORS treatment seeking outcomes.

Similarly, on a global level, the zinc and ORS scale-up program was implemented among select states in Nigeria (eight states) and India (three states) and the program was implemented at a country level in Uganda and Kenya. Researchers sought to assess scale-up of zinc and ORS across high burden settings and found that increases in pediatric diarrheal treatment rates are possible at a large scale. For each country, researchers used a triangulation-based approach by collecting data from household surveys (DHS datasets), public facility audits, and private outlet surveys to obtain baseline, midline, and endline surveys. To compare the target countries, researchers used neighboring countries as a control by collecting DHS and MICS surveys from countries in Sub-Saharan Africa, Asia, Middle East, and Eastern Europe (11).

In terms of outcomes, researchers specifically measured changes in zinc and ORS coverage and changes in ORS coverage. Researchers then measured changes for ORS and zinc coverage in percentage points per year via an ordinary least squares method. Additional subgroup analyses were conducted across wealth quintiles and type of residence (urban/rural) to determine if coverage was equally observed across subgroups.

First, researchers compared baseline and endline changes within each program area. In terms of ORS coverage, researchers found statistically significant increases in India and Nigeria with ORS coverage in targeted states in India increasing from 22% to 48% and in Nigeria ORS coverage in targeted states increasing from 38% to 55% (11). In terms of zinc and ORS coverage,there were statistically significant increase in coverage changes across all four targeted areas (11). Lastly, there were coverage increases in both rural and urban areas and across wealth quintiles (11).

When compared to the control regions or neighboring regions, researchers compared pre-intervention periods (2008-2012) with during intervention and post-intervention periods (2012-2016). When comparing coverage changes in surrounding countries in the Sub-Saharan Africa region as controls to the intervention countries Uganda, Kenya, and Nigeria, between 2008-2012, researchers found an average annual increase of 0.1 percentage points in zinc and ORS coverage for Sub-Saharan Africa and 1.2, 0.2, and 0.5 percentage points for Kenya, Uganda, and selected states in Nigeria, respectively (11). Between 2012-2016, researchers found an increase of 2.2 percentage points per year in sub-Saharan Africa and 2.6, 7.1, and 7.2 for Kenya, Uganda, and selected states in Nigeria, respectively (11).

Though the study presents a control group which strengthens the validity of results, the study does not account for potential confounders. As a result, this study also presents concerns with rigor in methods. Usage of neighboring countries as a control can also present a potential concern as using the Sub-Saharan Africa region as a control for individual countries with diverse cultures, geography, and demographic characteristics may not be representative as a control. Additionally, the study notes a statistically significant increase in ORS coverage only in areas where the program was implemented in select states. It is a potential point of concern as the study found no statistical significance was found in ORS coverage in Uganda and Kenya in which the program was scaled up to a country level.

Overall, previous studies that have evaluated the efficacy of the zinc and ORS scale-up program have not utilized rigorous methods, and the results researchers have found cannot be causally attributed to the zinc and ORS scale-up program. As a result, there is a notable gap in the literature for a causal impact study conducted on this zinc and ORS up program implemented by CHAI. Given the scope of the zinc and ORS scale-up program, it is particularly salient to conduct a rigorous analysis of the program on zinc and ORS treatment uptake.

Methods:

3.1 Study Design and Setting:

The intervention was conducted across eight states: Bauchi, Cross River, Kaduna, Kano, Katsina, Lagos, Niger, and Rivers. The states were specifically selected as they cover five out of the six Nigeria geopolitical zones (Southeast not included) and represent a wide range of cultural, health, and economic outcomes (11). Across the selected states, diarrheal disease is the leading cause of death in children under five years, and the eight states accounted for over eight million children in 2017 (approximately over 25% of the children under five years population in Nigeria) and 40% of the total pediatric diarrheal burden in Nigeria (8,11, 37).

We conducted a difference-in-difference analysis (DiD) to evaluate whether there was a causal impact of the zinc and ORS scale-up program on the intended outcome of increasing treatment-seeking behavior for child diarrhea in the eight states that received the intervention. DiD is a quasi-experimental research design that combines insights from cross-sectional treatment-control comparisons and before-after studies to eliminate the influence of outside/unobservable factors (12).

We ran a DiD analysis with two time periods (2008 and 2018) with a fixed effects models and compared the changes in outcomes over time between the states that did not receive the program and the states that did (13). DiD specifically compares two differences: (1) the first difference accounts for time and subtracts before and after changes in both treatment and control groups and (2) the second difference takes the differences between treatment and control groups (13). The difference with before and after studies is that the two differences are compared to eliminate selection bias and differences in unobservable characteristics (13). In this study, there are two time points (2008 and 2018) and the difference across the two time points were observed while controlling for state fixed effects. Thus, the difference-in-difference is taken and the causal impact of the program can be assessed. Additional details of DiD and its impact in public health interventions can be found in *Impact Evaluation in Practice* (13).

3.2 Data and Variables:

Data collection came from the KR (Children's Recode) data from 2008 and 2018 Nigeria Demographic Health Survey (NDHS) datasets, a publicly available national sample survey that provides demographic and health indicators. The datasets cover Nigeria's six geopolitical zones and 36 states and the Federal Capital Territory (FCT).

Because NDHS datasets are publicly anonymized data and the DiD analysis would not pose a risk or harm to subjects, the study is considered not human subjects research, and Institutional Review Board (IRB) approval was not sought for the study/analysis.

The study population were children under five years that were diagnosed with diarrheal disease 2 weeks before the DHS was conducted in Nigeria's 37 states. In the KR files, the population size for the NDHS 2008 dataset was approximately 36,000 households and the population size for the NDHS 2018 dataset was approximately 42,000 households. In terms of sampling and recruitment for the surveys, NDHS utilizes probability multi-stage clustering sampling and survey weighting for both 2008 and 2018 datasets. Because the outcome of the study is the percentage of children with diarrhea disease who sought treatment or advice, the target population for this study is the number of children who were diagnosed with diarrheal disease 2 weeks before the DHS was conducted (6,601 children). Breaking down the sample population size further, there were 2,645 children in 2008 and 3,956 children in 2018. Variations throughout the time period such as seasonality were not considered in the analysis as there was limited literature that affirmed seasonality as a determinant of diarrheal treatment uptake.

In our study, the NDHS KR 2008 and NDHS KR 2018 datasets were appended through STATA for the DiD analysis. The independent variables are the year, whether or not a state received the intervention, and factors that impact access to diarrheal treatment. The dependent variable or outcome of the study is the likelihood of a child's uptake of zinc or ORS treatment following a diarrheal episode and was measured through four different outcomes.

Because the intervention targeted a zinc and ORS scale-up, there were four outcome binary variables measured in the analysis on whether or not the child sought treatment following a diarrheal episode. First, the “zinctx” or zinc uptake variable was based on whether the child sought zinc treatment. The “orstx” or ORS uptake variable is based on whether the child sought ORS treatment. The “zincandorstx” or zinc and ORS uptake variable is based on whether the child sought both zinc and ORS treatment. The “zincororstx” or zinc or ORS uptake variable is based on whether the child sought zinc or ORS treatment or did not seek treatment at all. The zinc or ORS uptake variable was created as the most inclusive and the zinc and ORS uptake variable was created as the most restrictive.

Treatment uptake was measured rather than diarrheal disease prevalence as the program did not target diarrheal disease prevalence but rather the downstream effects of the treatment step when children already have diarrheal disease. Mortality due to diarrheal disease was not measured as the NDHS datasets do not include variables on individual child mortality due to diarrheal disease.

In terms of independent variables, we created a year variable and intervention state variable. For the year variable, the year was either 2008 (pre-intervention) or 2018 (post-intervention). For whether or not the state received the intervention, an intervention state variable was created in which the 29 states that did not receive the intervention were coded as control states and the eight states that received the intervention were coded as intervention states, so all states were included in the analysis. Definitions such as what qualifies as having diarrheal disease and diarrheal treatment or advice adhere to the respective definitions in the NDHS datasets (5,14).

To assess causal impact of the program on treatment uptake for diarrheal disease, an interaction variable that combined the year and intervention state variable was created.

The variables selected that impact access to treatment were age, sex, formal education of mother, type of place of residence (urban or rural), childhood vaccine uptake (specifically, receiving the DPT3 vaccine), wealth quintiles, and difficulty seeking care. These specific variables were selected as factors that impact access to treatment based on existing literature and a logit regression that was run for each variable on the appended dataset to test for statistical significance (15-19). Controls included in the analysis were either derived from NDHS variables or taken directly. A more specific rationale as to why each variable can be found in S.1 and specific definitions of the variables can be found in Table 1.

Table 1: Variable definitions used across models

Variable	Definition
Outcomes	
Zinc uptake	Whether the child under five years with diarrheal disease sought zinc treatment or not
ORS uptake	Whether the child under five years with diarrheal disease sought ORS treatment or not
Zinc and ORS uptake	Whether the child under five years with diarrheal disease sought zinc and ORS treatment or didn't seek both
Zinc or ORS uptake	Whether the child under five years with diarrheal disease sought zinc or ORS treatment or didn't seek either
Controls	
Individual Level Variables *	
Sex	Biological sex of child that can be categorized into either male or female
Age of child	Age is by years calculated based on DHS definitions of age in months (0-11 months, 12-23 months, 24-35 months, 36-47 months, and 48-59 months)
Household Level Variables *	

Wealth quintile	A composite measure of household's cumulative living standard based on house ownership and select assets.
Educational attainment of mother	Educational attainment of women ages 15-49 based on highest level of education completed across no education, incomplete primary education, primary education, incomplete secondary education, secondary education, and higher than secondary education
Difficulty seeking care	Difficulty seeking care was based on NDHS variables that consisted of whether or not it presented as a big problem or not in getting money needed for treatment, distance to health facility, mother needing permission to go seek treatment for the child, and mother not wanting to go alone. The difficulty seeking care variable was created using the factors listed above from the dataset and creating a binary variable for each factor (1 being a big problem and 0 being not a problem) and averaging the factors for each child
Community Level of Variables	
DPT3 Community Vaccination	The proportion of children that received the DPT3 vaccine that is averaged and grouped per primary sampling unit.
Type of residence	Type of residence is categorized into living in an urban region or rural region

The table provides definitions of variables that were included in the models that were run during the statistical analysis. A "*" indicates that the definitions were directly taken from the Demographic Health Survey (DHS) manual for variables.

3.3 Statistical Analysis:

To assess if any changes in treatment outcome were attributed to the zinc and ORS scale up program, a logit regression with robust standard errors and individual, household, and community-level variables was fit using a DiD framework and run through STATA/SE 18.0.

To satisfy the DiD framework, the parallel trends assumption or the assumption that the treatment group will follow the same time trend as the control group if the intervention did not take place must be satisfied (12). Evidence of such parallel trends can be found in S.8.

The DiD framework compares the difference in change of treatment uptake of intervention states compared to control states while controlling for individual, household, and community-level variables. The outcome or "Treatment uptake$_{ij}$" is a binary variable that describes whether treatment or advice was sought for diarrheal disease for child *i* in year *j* (where *j* is 2008 or 2018). Specifically, there were 2,645 children in 2008 and 3,956 children in 2018. Because there are four different binary outcome variables (zinc, ORS, zinc and ORS, zinc or ORS) that indicate treatment uptake, "Treatment uptake$_{ij}$" is a general outcome that can be substituted with the four measured outcomes. As shown in the regression in Equation 1, intervention state indicates whether the child is living in a state that received the program (coded as 1 for intervention states and 0 for control states). "Year" indicates whether the time period was before or after the intervention took place (coded as 1 for 2018 and 0 for 2008). Equation 1 represents the baseline model and does not control for individual, household, or community level variables.

Equation 1:

$$Logit(Treatment\ Uptake_{ij}) = \beta_0 + (\beta_1 \times Intervention\ State_{ij}) + (\beta_2 \times Year_i) + (\beta_3 \times Intervention\ State_{ij} \times Year_i)$$

The effect of the ORS and zinc scale-up program on treatment uptake is measured by the interaction between whether the state received the intervention program (intervention state) and on whether the outcome was measured in 2008 or 2018 (Year). β_3 is the coefficient that quantifies the causal impact of the intervention program on diarrheal treatment uptake, specifically the estimated difference between intervention and control states in the 2008 to 2018 change in the odds of uptake.

Because the outcome for treatment uptake is binary, a logistic regression with fixed effects was run on the four outcome variables with four models that controlled for different levels of variables for each outcome variable. For all four models, standard errors were clustered at the state level with robust standard errors. Model 1 was a base model with year, intervention state, the interaction variable and one of the dependent variables (zinc, ORS, zinc and ORS, zinc or ORS). Model 2 included all independent variables of the base model and additionally controlled for individual-level variables (child age and child sex). Model 3 included all independent variables of the baseline model controlled for individual and household-level variables (age, gender, difficulty seeking care, wealth quintile, and mother's educational attainment). Model 4 controlled for all independent variables of the baseline model , as well as individual, household, and community-level variables (age, gender, difficulty seeking care, wealth quintile, mother's educational attainment, community DPT3 vaccine uptake, and type of place of residence (urban or rural). The ratio of odds ratios was used to assess the likelihood of receiving zinc and ORS treatment after a diarrheal episode.

When running the logit models and creating the variables, to ensure the sample size was the same across the four models, missing values were dropped when performing the statistical analysis. Among the 6,601 children in the sample size, there were 166 missing values that were dropped during the analysis based on availability of data from several control variables (i.e., difficulty seeking care varaiable).

3.4 Subgroup and Sensitivity Analysis:

Subgroup analyses were conducted to assess whether the zinc and ORS scale up program improved treatment uptake on specific groups and to assess whether overlapping interventions blunted the observed impact of the zinc and ORS scale-up program. To test for disproportionate distribution of the intervention, a subgroup analysis was conducted on poor (poorest and poorer wealth quintile) and nonpoor groups (middle, rich, and richest wealth quintile). The poor population consists of the bottom two wealth quintiles, as the poverty rate in Nigeria at the time of the intervention was about 40% (20). Additionally, because the intervention focuses on expanding zinc and ORS coverage to rural areas, a subgroup analysis was conducted on urban and rural groups. Model 2 and Model 3 were run on each subgroup, with the wealth quintile variable omitted for the wealth subgroup analysis and the place of residence variable omitted for the urban/rural subgroup analysis. Results for the subgroup analysis can be found in S.4.

As mentioned in the literature review, an iCCM strategy was implemented in Abia and Niger state from 2013-2017 to scale up diagnostic, treatment, and referral services for common childhood illnesses including diarrheal disease (21). Because there is an intervention period overlap between iCCM and the zinc and ORS scale-up program, there may have been effects on zinc and ORS treatment uptake in Abia (control state) and Niger (intervention state) that will blunt the observed effects of the CHAI program. As a result, an additional subgroup analysis was conducted that excluded children under five years with diarrheal disease in Abia and Niger state and the same four outcomes were assessed across Models 1-4.

To conduct the sensitivity analysis, the intervention states remained the 8 states that received the intervention (Bauchi, Cross River, Kaduna, Kano, Katsina, Lagos, Niger, and Rivers). For the control states, the control states were narrowed down to states that shared borders with the 8 intervention states (Jigawa, Yobe, Gombe, Plateau, Akwa Ibom, Kebbi, Anambra, Zamfara, Kwara, Kogi, Abuja, Ogun, Benue, Nasarawa, Ebonyi, Bayelsa, Abia, Delta, and Imo). Control states were narrowed to account for potential spillover effects if main results show a statistically significant increase in treatment uptake and increase robustness of main analyses findings. A new interaction variable was created with the new treatment and control groups and the same year variable. Model 4 for each of the four outcome variables were run with the new interaction variable. The results of the sensitivity analysis can be found in S.5.

3.5 Likelihood Ratio (LR) Test and Hausman Test:

An LR test was applied to each of the models across the four outcome variables in order to test if there was any statistically significant difference between the models. The LR test was run between Model 1 and 2, Model 2 and 3, and Model 3 and 4. The results of the LR test can be found in S.6.

The Hausman test was applied to Model #4 across the four outcome variables in order to test if there was a statistically significant difference between state fixed effects and random effects. An additional analysis was run on Model #4 with fixed effects removed (removal of "sstate variable") and fixed effects versus random effects were compared via a Hausman test. The results of the Hausman test can be found in S.7.

Results:

Descriptive data summary:

Table 2: Baseline characteristics of children under five years who had diarrhea in the two weeks by percentage (NDHS 2008)

Variables	Intervention States	Control States	P-value
	N= 7,851	N= 20,796	
Educational attainment of mother			0.00 **

No education	38%	28%	
Incomplete primary	6%	9%	
Complete primary	16%	22%	
Incomplete secondary	13%	17%	
Complete secondary	20%	17%	
Higher	8%	7%	
Wealth Index			0.00 **
Poorest	16%	17%	
Poorer	20%	19%	
Middle	19%	22%	
Richer	16%	23%	
Richest	28%	18%	
Child Current Age (Years)	1.90 ± 0.01	1.91 ± 0.02	0.78
Child Sex			0.79
Female	49%	49%	
Male	51%	51%	
DPT coverage (community level)	0.40 ± 0.02	0.44 ±0.04	0.00 **
Type of Residence			0.00 **
Rural	62%	71%	
Urban	38%	29%	
Difficulty Seeking Care	0.31 ± 0.02	0.33 ±0.04	0.00 **
Percentage that sought treatment: Zinc	1.01%	0.44%	0.23
Percentage that sought treatment: ORS	31.17%	30.89%	0.61
Percentage that sought treatment: Zinc and ORS	0.52%	0.21%	0.42

Percentage that sought treatment: Zinc or ORS	31.79%	30.19%	0.53

Descriptive analysis uses the total sample size of the NDHS 2008 KR data. Proportions were used for educational attainment of mother, wealth index, gender, and type of residence. Means and standard errors were used for age, DPT coverage, and difficulty seeking care. Survey weights were applied during the descriptive analysis. "*" indicates if p≤0.05 and "**" indicates if p≤0.01.

Table 2 shows a summary of study population characteristics comparing intervention states and control states in 2008 before the intervention was applied. Prevalence of diarrheal disease was statistically significantly higher in treatment states than control states (10.84% for treatment states and 6.54% for control states).

In terms of highest educational attainment of the mother, the proportion for no education (0.38 for treatment states and 0.28 for control states), complete secondary (0.20 for treatment states and 0.17 for control states), and higher than secondary (0.08 for treatment states and 0.07 for control states) was statistically significantly higher in treatment states than control states. The proportion of incomplete primary (0.06 for treatment states and 0.09 for control states), complete primary (0.16 for treatment states and 0.22 for control states), and incomplete secondary (0.13 for treatment states and 0.17 for control states) was statistically significantly higher in control states than treatment states.

In terms of wealth index, the proportion of households in the poorer (0.20 in treatment states and 0.19 in control states) and richest (0.28 in treatment states and 0.18 in control states) categories were statistically significantly higher in treatment states than control states. The proportion of households in the poorest (0.16 in treatment states and 0.17 in control states), middle (0.19 in treatment states and 0.22 in control states), and richer (0.16 in treatment states and 0.23 in control states) categories were statistically significantly higher in control states than treatment states.

In terms of DPT3 vaccine coverage, at a community level, there was a statistically significantly higher mean proportion of children under five years vaccinated for the DPT3 vaccine in control states than treatment states (0.40 ± 0.02 for treatment states and 0.44 ± 0.04 for control states).

In terms of type of residence there was a statistically significantly higher proportion of households living in urban regions in treatment states than control states (0.38 for treatment states and 0.29 for control states).

Lastly, in terms of access to care, there was a statistically significantly higher mean proportion of households facing a problem seeking care for control states than treatment states (0.31 for treatment states and 0.33 for control states) .

State-Level Differences:

In terms of directly comparing proportion of treatment uptake in 2008 vs 2018, Figures 1a-1d depicts scatter plots that compares changes in treatment uptake across all four outcomes.

Overall, across all four outcomes, there was an overall higher proportion of treatment uptake in the endline (2018) compared to the baseline (2008) across both intervention states and control states. For zinc treatment uptake and zinc and ORS treatment uptake, there were more states above the 45º degree line of equality, indicating more intervention and control states with an increase in zinc uptake and zinc and ORS treatment uptake between 2008 and 2018.

Figure 2a:

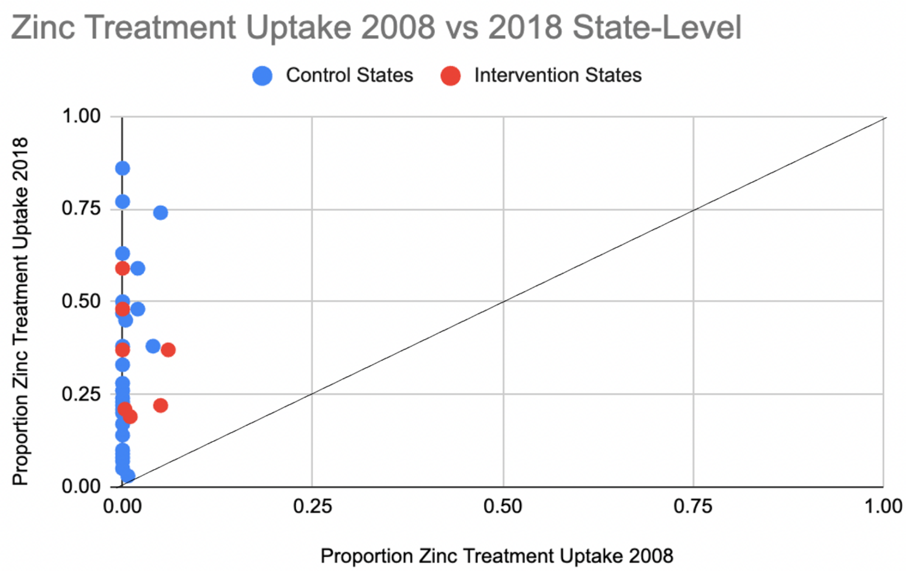


Figure 2b:

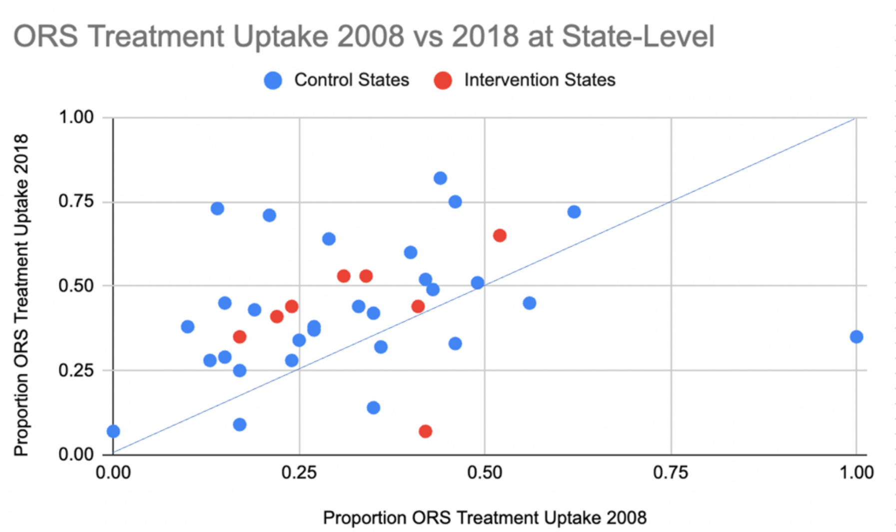


Figure 2c:

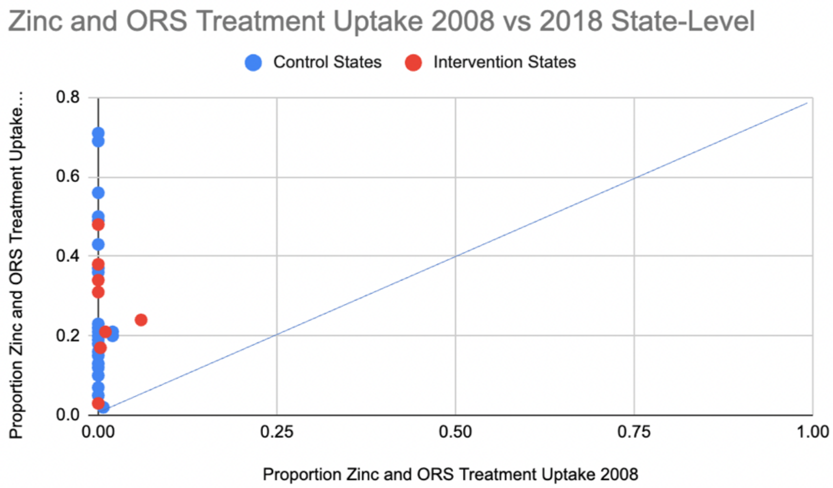
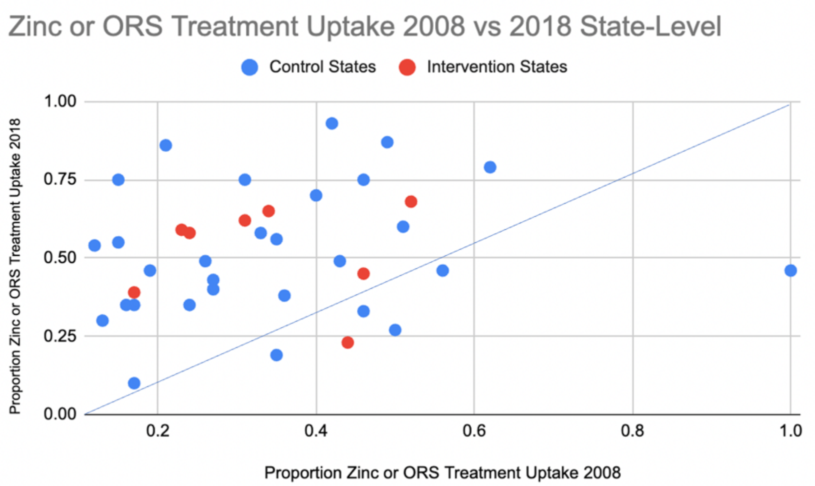


Figure 2d:



Figures 1a-1d: Figures depict a scatter plot comparing proportion of treatment uptake in 2008 vs 2018 across all four outcomes. A 45º degree line of equality was included in each scatter plot to assess which states sought more treatment at the endline (2018) compared to the baseline (2008).

Observing changes in treatment uptake in specific states, an additional descriptive summary was conducted on treatment uptake at state level across four treatment uptake outcomes (zinc only, ORS only, zinc and ORS, zinc or ORS). As shown in Figure 1a-1d, there are overall increases in proportion of treatment uptake across all four outcomes regardless of intervention and control state status. In terms of ORS treatment uptake and zinc or ORS treatment uptake, there were decreases in proportion of treatment uptake in both intervention and control states.

Figure 2a:

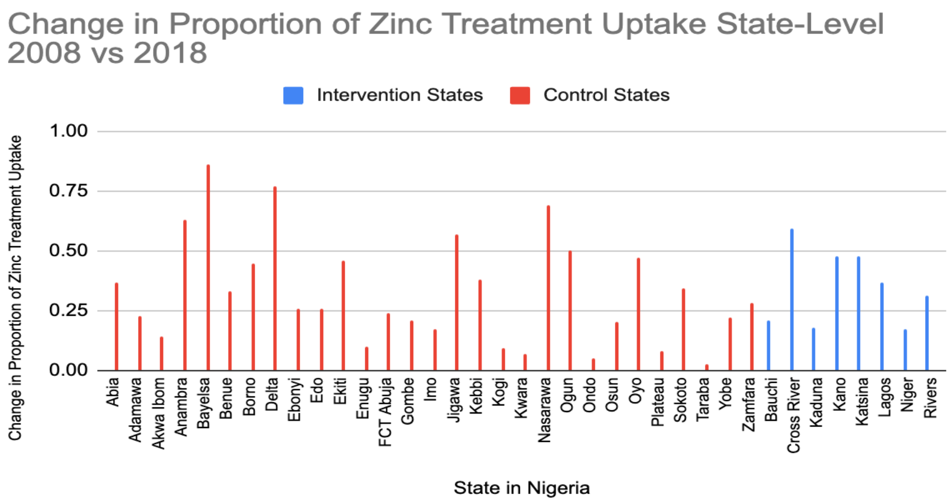


Figure 2b:

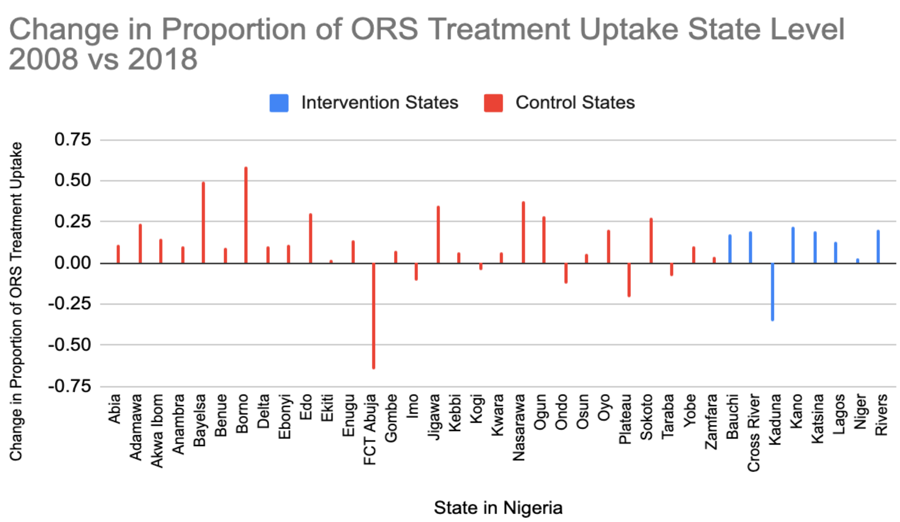


Figure 2c:

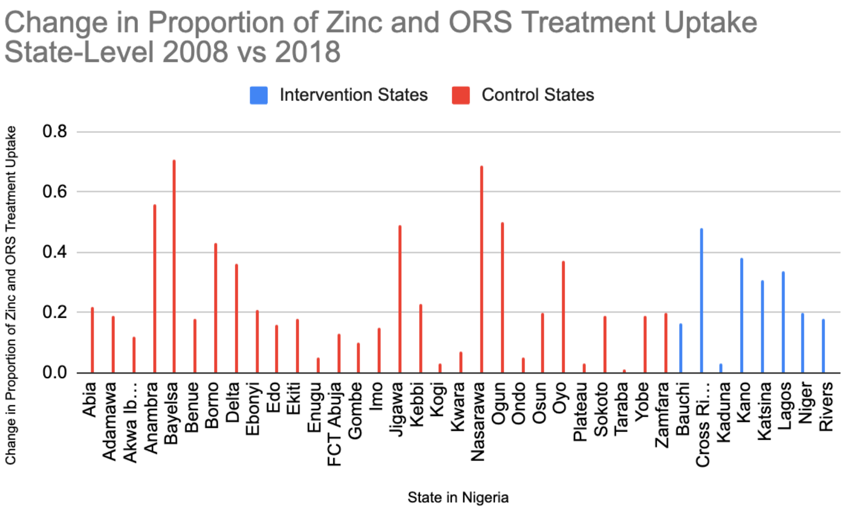
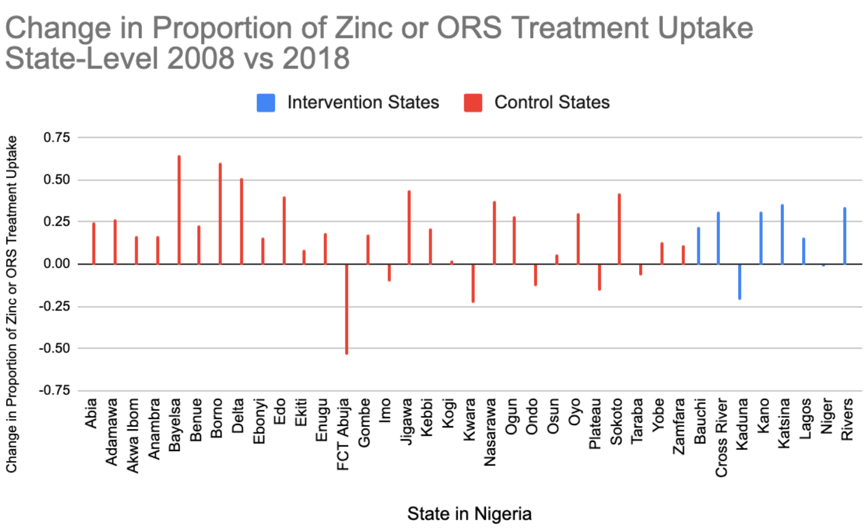


Figure 2d:



Figures 2a-2d: Figures depict state level changes in proportion of four treatment uptake outcomes in 2018 compared to 2008. Red bars indicate control states and blue bars indicate intervention states.

Treatment Uptake Analysis:

Table 3.1: Treatment sought for Zinc

	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Odds Ratio				
Year	85.21 (34.78, 208.77) **	85.19 (34.74, 208.95) **	79.43 (33.48, 188.44) **	70.49 (29.62, 167.75) **
Intervention_state	0.94 (0.17, 5.14)	0.95 (0.17, 5.20)	0.37 (0.07, 1.97)	0.30 (0.06, 1.54)
Interaction (Treatment Effect)	0.90 (0.16, 5.22)	0.91 (0.16, 5.22)	0.89 (0.16, 4.88)	0.85 (0.16, 4.57)

Table 3.1 shows the odds ratio of children under five years seeking zinc treatment. Model 1 is the baseline model, Model 2 controls for individual variables (age and gender), Model 3 controls for individual and household variables (age, gender, wealth, education of mother, and difficulty seeking care), and Model 4 controls for individual, household, and community variables (age, gender, wealth, education of mother, difficulty seeking care, place of residence, and DPT_comm) . State fixed effects were applied to each model. "*" indicates if $p \leq 0.05$ and "**" indicates if $p \leq 0.01$. For the interaction term, because we are comparing differences across a time period with differences between control and intervention states using a logit function, the interaction represents a "ratio of odds ratios."

Table 3.2: Treatment sought for ORS

	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Odds Ratio				
Year	1.94 (1.25, 3.02) **	1.94 (1.25, 3.02) **	1.90 (1.25, 2.88) **	1.70 (1.14, 2.55) *
Treatment_state	4.47 (3.15, 6.35) **	4.45 (3.15, 6.30) **	1.64 (1.08, 2.50) *	1.22 (0.72, 2.08)

Interaction (Treatment Effect)	0.96 (0.51, 1.82)	0.96 (0.51, 1.82)	0.92 (0.49, 1.76)	0.90 (0.48, 1.67)

Table 3.2 shows odds ratio of children under five years seeking ORS treatment. Model 1 is the baseline model, Model 2 controls for individual variables (age and gender), Model 3 controls for individual and household variables (age, gender, wealth, education of mother, and difficulty seeking care), and Model 4 controls for individual, household, and community variables (age, gender, wealth, education of mother, difficulty seeking care, place of residence, and DPT_comm) . State fixed effects were applied to each model. "*" indicates if p≤0.05 and "**" indicates if p≤0.01. For the interaction term, because we are comparing differences across a time period with differences between control and intervention states using a logit function, the interaction represents a "ratio of odds ratios."

Table 4.1: Treatment Sought for both Zinc and ORS:

	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Odds Ratio				
Year	156.68 (40.70, 603.06) **	156.38 (40.63, 601.86) **	141.66 (38.24, 524.71) **	125.34 (33.77, 465.16) **
Intervention_state	2.42 (0.39, 14.98)	2.48 (0.40, 15.53)	1.07 (0.18, 6.21)	0.87 (0.15, 4.92)
Interaction (Treatment Effect)	0.74 (0.12, 4.71)	0.74 (0.12, 4.71)	0.76 (0.13, 4.51)	0.73 (0.12, 4.30)

Table 4.2: Treatment Sought for Zinc or ORS:

	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Odds Ratio				

Year	2.74 (1.76, 4.25) **	2.74 (1.77, 4.25) **	2.69 (1.76, 4.14) **	2.40 (1.58, 3.66) **
Intervention_state	3.07 (2.17, 4.35) **	3.05 (2.16, 4.31) **	0.93 (0.64, 1.35)	0.67 (0.41, 1.11)
Interaction (Treatment Effect)	0.95 (0.50, 1.82)	0.95 (0.50, 1.83)	0.91 (0.48, 1.71)	0.87 (0.48, 1.59)

The first table shows the odds ratio of children under five years seeking both zinc and ORS treatment (less inclusive). The second table shows the odds ratio of children under five years seeking either zinc or ORS treatment (more inclusive). Model 1 is the baseline model, Model 2 controls for individual variables (age and gender), Model 3 controls for individual and household variables (age, gender, wealth, education of mother, and difficulty seeking care), and Model 4 controls for individual, household, and community variables (age, gender, wealth, education of mother, difficulty seeking care, place of residence, and DPT_comm) . State fixed effects were applied to each model. "*" indicates if $p \leq 0.05$ and "**" indicates if $p \leq 0.01$. For the interaction term, because we are comparing differences across a time period with differences between control and intervention states using a logit function, the interaction represents a "ratio of odds ratios."

No statistically significant changes in treatment uptake across all four outcomes (zinc uptake, ORS uptake, zinc and ORS uptake, zinc or ORS uptake) for children under five years with diarrheal disease.

In Table 3.1, for whether or not the child sought zinc treatment, in Model 1, the estimated treatment effect was a ratio of odds ratio (ROR) of 0.90 (95% CI=0.16, 5.22), representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 2 adjusted for individual (current age of child, and gender of child). The estimated treatment effect was a ROR of 0.91 (95% CI=0.16, 5.22) representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 3 adjust for household (wealth, education of mother, and difficulty seeking care) along with individual variables. The estimated treatment effect was a ROR of 0.89 (95% CI= 0.16, 4.88), representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 4 adjusted for community variables (DPT_comm and type of place of residence) along with the individual and household variables in Model 3. The estimated treatment effect was a ROR of 0.85 (95% CI=0.16, 4.57), representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

In Table 3.2, for whether or not the child sought ORS treatment, in Model 1 and Model 2, the estimated treatment effect was a ROR of 0.96 (95% CI=0.51, 1.82), representing the change in odds of ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 3, the estimated treatment effect was a ROR of 0.92 (95% CI=0.49, 1.76)), representing the change in odds of ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 4, the estimated treatment effect was a ROR of 0.90 (95% CI=0.48, 1.67)), representing the change in odds of ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

In Table 4.1, four models were run to assess the causal impact of the intervention on treatment seeking behavior among children under five years. Across the four models, the models accounted for varying factors with Model 4 including individual, household, and community-level controls. Among the four models across the four outcome variables, there were no statistical significant changes in treatment seeking behavior in children under five years that could be attributed to the intervention.

For whether the child sought both zinc and ORS treatment, in Model 1 and 2, the estimated treatment effect was a ROR of 0.74 (95% CI=0.12, 4.71), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 3, the estimated treatment effect was a ROR of 0.76 (95% CI=0.13, 4.51), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 4, the estimated treatment effect was a ROR of 0.73 (95% CI=0.12, 4.30), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

For whether the child sought zinc or ORS treatment or no treatment, in Model 1, the estimated treatment effect was a ROR of 0.95 (95% CI=0.50, 1.82), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 2, the estimated treatment effect was a ROR of 0.95 (95% CI=0.50, 1.83), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 3, the estimated treatment effect was a ROR of 0.91 (95% CI=0.48, 1.71), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 4, the estimated treatment effect was a ROR of 0.87 (95% CI=0.48, 1.59), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

There was a temporal increase in likelihood of receiving zinc treatment, ORS treatment, zinc and ORS treatment, and zinc or ORS treatment among both control and intervention states comparing 2008 and 2018, with 2018 having a higher odds of receiving zinc treatment and ORS treatment.

Temporal Effects:

For whether the child sought zinc treatment, in Model 1, there was a 85.21 (95% CI=34.78, 208.77) times odds of receiving zinc treatment in both treatment and control states in 2018 compared to 2008. In Model 2, there was a 85.19 (95% CI=34.74, 208.95) times odds of receiving zinc treatment in both treatment and control states in 2018 compared to 2008. In Model 3, there was a 79.43 (95% CI=33.48, 188.44) times odds of receiving zinc treatment in both treatment and control states in 2018 compared to 2008. In Model 4, there was a 70.49 (95% CI=29.62, 167.75) times odds of receiving zinc treatment in both treatment and control states in 2018 compared to 2008.

For whether the child sought ORS treatment, in Model 1, there was a 1.94 (95% CI=1.25, 3.02) times odds of receiving ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 2, there was a 1.94 (95% CI=1.25, 3.02) times odds of receiving ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 3, there was a 1.90 (95% CI=1.25, 2.88) times odds of receiving ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 4, there was a 1.70 (95% CI=1.14, 2.55) times odds of receiving ORS treatment in both treatment and control states in 2018 compared to 2008.

In Table 4.2, across all models for both the zinc and ORS and zinc or ORS outcomes, there was a statistically significant increase in likelihood of receiving zinc and/or ORS treatment in 2008 and 2018 among both treatment and control states.

For whether the child sought both zinc and ORS treatment, in Model 1, there was a 156.68 (95% CI=40.70, 603.06) times odds of receiving zinc and ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 2, there was a 156.38 (95% CI=40.63, 601.86) times odds of receiving zinc and ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 3, there was a 141.66 (95% CI=38.24, 524.71) times odds of receiving zinc and ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 4, there was a 125.34 (95% CI=33.77, 465.16) times odds of receiving zinc and ORS treatment in both treatment and control states in 2018 compared to 2008.

For whether the child sought zinc or ORS treatment, in Model 1, there was a 2.74 (95% CI=1.76, 4.25) times odds of receiving zinc or ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 2, there was a 2.74 (95% CI=1.76, 4.25) times odds of receiving zinc or ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 3, there was a 2.69 (95% CI=1.76, 4.14) times odds of receiving zinc or ORS treatment in both treatment and control states in 2018 compared to 2008. In Model 4, there was a 2.40 (95% CI=1.58, 3.66) times odds of receiving zinc or ORS treatment in both treatment and control states in 2018 compared to 2008.

State Differences:

At baseline,the likelihood of uptake of zinc and ORS uptake in intervention states was on average higher than in control states. This effect disappears as individual, household, and community-level controls are added.

For ORS Model #1, Model #2, and Model #3, there was a statistically significant higher odds in receiving ORS treatment in treatment states compared to control states at baseline before the intervention was applied. In Model 1, there was a 4.47 (95% CI= 3.15, 6.35) times odds of receiving ORS treatments in treatment states than control states. In Model 2, there was a 4.45 (95% CI= 3.15, 6.30) times odds of receiving ORS treatments in treatment states than control states. In Model 3, there was a 1.64 (95% CI= 1.08, 2.50) times odds of receiving ORS treatments in treatment states than control states.Though, once individual, household, and community-level controls were all applied, there was no statistically significant difference of likelihood of receiving ORS treatment between treatment and control states.

For zinc or ORS Model 1 and Model 2, there was a statistically significant higher odds in receiving zinc or ORS treatment in treatment states compared to control states at baseline. In Model 1, there was a 3.07 (95% CI= 2.17, 4.31 times odds of receiving zinc or ORS treatments in treatment states than control states. In Model 2, there was a 3.05 (95% CI= 2.16, 4.31) times odds of receiving zinc or ORS treatments in treatment states than control states. Though, once community-level and household-level controls were added, there was no statistically significant difference of likelihood of receiving zinc or ORS treatment between treatment and control states.

When the LR test was run comparing Model 1 vs Model 2, Model 2 vs Model 3, and Model 3 vs Model 4, Model 4 was found to be the best fit. When the Hausman test was run, fixed effects were preferred to random effects (see S.6 and S.7).

Results of subgroup analyses

After running the four different subgroups across four outcome variables, there were statistically significant results found in the poor households for zinc and zinc or ORS treatment outcomes. There were also statistically significant results found in urban households for zinc or ORS treatment outcomes.

Table 5.1: Zinc and ORS separate subgroup analyses excluding iCCM states (Abia and Niger)

Treatment sought	Zinc				ORS			
	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Ratio of Odds Ratio								
Year	84.34 (34.38, 206.88) **	84.35 (34.38, 206.98) **	78.63 (33.13, 186.61) **	70.1 (29.50, 166.69) **	1.95 (1.25, 3.04) **	1.95 (1.25, 3.04) **	1.91 (1.25, 2.91) **	1.71 (1.13, 2.56) **
Treatment_statesub	0.41 (0.08, 2.07)	0.42 (0.08, 2.07)	0.16 (0.04, 0.74) *	0.14 (0.03, 0.60) **	4.36 (3.05, 6.22) **	4.34 (3.05, 6.16) **	1.65 (1.06, 2.56) *	1.23 (0.71, 2.13)
Limited Sample	2.10 (0.41, 10.82)	2.10 (0.41, 10.82)	2.04 (0.41, 10.19)	1.92 (0.38, 9.72)	1.03 (0.54, 1.96)	1.03 (0.54, 1.96)	0.95 (0.48, 1.88)	0.90 (0.46, 1.76)

Table 5.1 shows the ratio of odds ratio of children under five years seeking zinc treatment or ORS treatment with outcomes of children under five years from Abia state and Niger state excluded. Model 1 is the baseline model, Model 2 controls for individual variables (age and gender), Model 3 controls for individual and household variables (age, gender, wealth, education of mother, and difficulty seeking care), and Model 4 controls for individual, household, and community variables (age, gender, wealth, education of mother, difficulty seeking care, place of residence, and DPT_comm) . State fixed effects were applied to each model. "*" indicates if p≤0.05 and "**" indicates if p≤0.01.

Table 5.2: Zinc and ORS and Zinc or ORS subgroup analyses excluding iCCM states (Abia and Niger)

Treatment sought	Zinc and ORS				Zinc or ORS			
	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Ratio of Odds Ratio								
Year	155.35 (40.20, 600.24) **	155.04 (40.17, 498.33) **	140.37 (37.82, 520.98) **	124.48 (33.48, 462.85) **	2.74 (1.76, 4.28) **	2.74 (1.76, 4.28) **	2.70 (1.75, 4.17) **	2.41 (1.57, 3.70) **
Treatment_state	1.69 (0.23, 12.23)	1.72 (0.24, 12.49)	0.76 (0.12, 5.00)	0.63 (0.10, 4.04)	2.93 (2.08, 4.12) **	2.91 (2.07, 4.08) **	0.91 (0.62, 1.32)	0.66 (0.40, 1.10)
Interaction (Treatment Effect)	1.07 (0.14, 7.90)	1.07 (0.14, 7.91)	1.07 (0.15, 7.51)	1.02 (0.14, 7.19)	1.07 (0.57, 2.00)	1.07 (0.57, 2.00)	0.99 (0.53, 1.86)	0.93 (0.50, 1.72)

Table 5.2 shows the ratio of odds ratio of children under five years seeking zinc and ORS treatmen or zinc or ORS treatment with outcomes of children under five years from Abia state and Niger state excluded. Model 1 is the baseline model, Model 2 controls for individual variables (age and gender), Model 3 controls for individual and household variables (age, gender, wealth, education of mother, and difficulty seeking care), and Model 4 controls for individual, household, and community variables (age, gender, wealth, education of mother, difficulty seeking care, place of residence, and DPT_comm) . State fixed effects were applied to each model. "*" indicates if $p \leq 0.05$ and "**" indicates if $p \leq 0.01$.

To account for competing interventions (i.e. iCCM), we ran a separate regression that excluded states that received the iCCM program (Niger and Abia). We found no statistically changes in treatment uptake across all four outcomes (zinc uptake, ORS uptake, zinc and ORS uptake, zinc or ORS uptake) for children under five years with diarrheal disease.

For whether or not the child sought zinc treatment, in Model 1, the estimated treatment effect was a ROR of 2.10 (95% CI=0.41, 10.82, representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 2 adjusted for individual (current age of child, and gender of child). The estimated treatment effect was a ROR of 2.10 (95% CI=0.41, 10.82), representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 3 adjust for household (wealth, education of mother, and difficulty seeking care) along with individual variables. The estimated treatment effect was a ROR of 2.04 (95% CI= 0.41, 10.19), representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 4 adjusted for community variables (DPT_comm and type of place of residence) along with the individual and household variables in Model 3. The estimated treatment effect was a ROR of 1.92 (95% CI=0.38, 9.72), representing the change in odds of zinc treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

For whether or not the child sought ORS treatment, in Model 1 and Model 2, the estimated treatment effect was a ROR of 1.03 (95% CI= 0.54, 1.96), representing the change in odds of ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 3, the estimated treatment effect was a ROR of 0.95 (95% CI=0.48, 1.88)), representing the change in odds of ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 4, the estimated treatment effect was a ROR of 0.90 (95% CI=0.46, 1.76)), representing the change in odds of ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

For whether or not the child sought zinc and ORS treatment, in Model 1, the estimated treatment effect was a ROR of 1.07 (95% CI=0.14, 7.90)), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 2 adjusted for individual (current age of child, and gender of child). The estimated treatment effect was a ROR of 1.07 (95% CI=0.14, 7.91)), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 3 adjust for household (wealth, education of mother, and difficulty seeking care) along with individual variables. The estimated treatment effect was a ROR of 0.99 (95% CI= 0.53, 1.86)), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. Model 4 adjusted for community variables (DPT_comm and type of place of residence) along with the individual and household variables in Model 3. The estimated treatment effect was a ROR of 0.93 (95% CI=0.14, 7.19)), representing the change in odds of zinc and ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

For whether or not the child sought zinc or ORS treatment, in Model 1 and Model 2, the estimated treatment effect was a ROR of 1.07 (95% CI= 0.57, 2.00)), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 3, the estimated treatment effect was a ROR of 0.95 (95% CI=0.48, 1.88), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups. In Model 4, the estimated treatment effect was a ROR of 0.93 (95% CI=0.50, 1.72), representing the change in odds of zinc or ORS treatment uptake in the intervention states compared to the control states, after accounting for pre-treatment differences between the two groups.

Sensitivity Analysis:

Table 6.1: Sensitivity Analysis of all four outcomes using fully specified model

Treatment sought	Zinc Model 4 (95% CI)	ORS Model 4 (95% CI)	Zinc and ORS Model 4 (95% CI)	Zinc or ORS Model 4 (95% CI)
Ratio of Odds Ratios				
Interaction (Treatment Effect)	0.32 (0.052, 1.91)	1.02 (0.58, 1.78)	1.09×10^{-6} (2.18×10^{-7}, 5.46×10^{-6}) **	0.97 (0.55, 1.70)

Table S.5.1 shows the ratio of odds ratio of children under five years seeking only zinc treatment, only ORS treatment, both zinc and ORS treatment, and zinc or ORS treatment. The interaction term is between the year variable and intervention state variables with excluded control states that do not share a border with the intervention states. When running Model 4, the fully-specified model that controls for individual, household, and community level variables, the control states have been limited to just the states that share a border with the treatment states. "*" indicates if $p \leq 0.05$ and "**" indicates if $p \leq 0.01$.

After narrowing the control states to neighboring states and running the baseline model and the adjusted model for individual, household, and community variables, there were no statistically significant changes in uptake for diarrheal treatment in children under five years due to the intervention across the outcome variables except for zinc and ORS. For whether or not the child sought both zinc and ORS treatment, the estimated treatment effect was a ROR of

1.09×10^{-6} ($2.18\times$

10^{-7}, 5.46×10^{-6}), representing the change in odds of zinc and ORS treatment uptake in the

intervention states compared to the control states, after accounting for pre-treatment differences

between the two groups.

Subgroup Analyses:

Table 7.1: ORS only and Zinc or ORS wealth and region subgroup analyses treatment effect

Treatment sought	ORS				Zinc or ORS			
	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Ratio of Odds Ratio								
Rural Only	0.86 (0.41, 1.79)	0.86 (0.41, 1.78)	0.83 (0.40, 1.74)	0.80 (0.40, 1.61)	0.84 (0.40, 1.78)	0.84 (0.40, 1.78)	0.81 (0.39, 1.68)	0.77(0.39, 1.54)
Urban Only	1.01 (0.50, 2.04)	1.01 (0.502, 2.03)	0.92 (0.45, 1.86)	0.92 (0.46, 1.85)	1.02 (0.53, 1.96)	1.02(0.54, 1.95)	0.93 (0.48, 1.80)	0.93(0.48, 1.78)
Poor Households Only	0.85 (0.46, 1.54)	0.85 (0.46, 1.54)	0.84 (0.46, 1.54)	0.83 (0.47, 1.48)	0.83 (0.43, 1.61)	0.83 (0.43, 1.61)	0.82 (0.43, 1.56)	0.80 (0.44, 1.47)
Non-poor Households Only	0.97 (0.421, 2.24)	0.97 (0.42, 2.24)	0.97 (0.41, 2.27)	0.92 (0.39, 2.19)	0.97 (0.43, 2.17)	0.97 (0.43, 2.17)	0.97 (0.43, 2.20)	0.92 (0.41, 2.09)

Table 7.1 shows the ratio of odds ratio of children under five years seeking ORS only and zinc or ORS treatment separated by rural only populations, urban only populations, poor households only, and non-poor households only. The interaction term is between the year variable and intervention states variable. Model 1 is the baseline model, Model 2 controls for individual variables (age and gender), Model 3 controls for individual and household variables (age, gender, wealth, education of mother, and difficulty seeking care), and Model 4 controls for individual,

household, and community variables (age, gender, wealth, education of mother, difficulty seeking care, place of residence, and DPT_comm) . State fixed effects were applied to each model. "*" indicates if $p \leq 0.05$ and "**" indicates if $p \leq 0.01$. Zinc only and zinc and ORS outcomes were not included because models failed to converge.

In subgroup analysis by wealth (poor and nonpoor) and by geographic location (rural and urban), there was no statistically significant changes in treatment uptake across ORS uptake and zinc or ORS uptake for children under five years with diarrheal disease.

Discussion:

I applied DiD analysis through a logit regression to determine whether there was a causal impact of the intervention on access to diarrheal treatment/care among children under five years. This study has revealed several principal findings. First, our analyses show that given individual, household, and community level variables controlled, there was no statistically significant causal impact of the zinc and ORS scale-up program on treatment uptake. There was a temporal increase in likelihood of receiving zinc treatment and ORS treatment among both control and intervention states comparing 2008 and 2018 with 2018 having a higher likelihood of receiving zinc treatment and ORS treatment. In other words, our analysis found that access to zinc and/or ORS improved across Nigeria but there was no differential impact of the program implemented by CHAI on that increase. This could have been because there were other intervention programs that may have been occurring around this time, or the program may not have been implemented extensively across the states.

I specifically utilized DiD as a causal approach that tests impact of the zinc and ORS scale-up program on zinc and ORS treatment uptake. The study specifically controlled for year, individual, household, and community levels to ensure that the differences in treatment uptake among children could be attributed to the intervention. Through DiD, the study extends beyond comparing outcomes between the treatment and control states; rather, by comparing the two differences outlined in the methodology (differences between treatment and control group and differences between pre-intervention and post-intervention), the DiD controls for observed time invariant characteristics and unobserved time invariant characteristics by comparing trends between the treatment and control states. Additionally, the study uses household data from NDHS, a comprehensive cross-sectional dataset that directly tests treatment seeking behavior and has available data on distinctions in treatment uptake in urban and rural regions once the intervention was applied. Lastly, a particular strength of this study is that based on a review of the literature, no other study has performed rigorous methods or DiD analysis to evaluate if there was a causal impact on treatment uptake of zinc and ORS.

In terms of limitations of the study, if there were any other factors that were not accounted for in the regression that impacted the differences in treatment uptake, it could impact the results of the DiD analysis. The impact of the program may have varied across the time period and thus results can be interpreted according to the zinc and ORS scale-up program time frame. Additionally, longitudinal data or data collected over a continuous period was not collected, instead cross-sectional data was collected and the same households were not tested in 2008 and 2018.

In terms of the outcome, there is limited data regarding mortality due to diarrheal disease which may have been impacted by the program. However, because there are no significant changes in treatment uptake due to the program, it is likely there are no significant changes in diarrheal disease mortality due to the program. Lastly, findings from this study are specific to an intervention program targeting children under five years in Nigeria, a high burden country for diarrheal disease. Findings from this study may not be easily generalizable to other LMIC that may not be as populated or suffer from the same disease burden as Nigeria.

Results of the study do not support previous studies that have evaluated impact of the program, but previous studies did not use rigorous methods. Specifically, before and after studies found odds of diarrhea being treated with ORS and zinc and ORS higher after program implementation compared to baseline before program implementation with a pro-rural increase and a reduction in wealth disparity gaps after program implementation (9,10). Other studies assessed causal impact via ordinary least squares methods and found a statistically significant increase in ORS coverage in India and Nigeria after program implementation compared to before program implementation (11). However, studies that assessed the impact of the zinc and ORS scale-up program lacked comprehensive methods, either through a lack of control group or failure to control for potential confounding factors.

The implications of this study is wide-ranging. More rigorous methods are needed for program evaluations as before and after studies are not sufficient to determine if changes in outcomes can be attributed to the program due to lack of controls for confounding factors. Additional research can also be done to determine what parts of the zinc and ORS scale up program implemented by CHAI did or did not work.

Because there were no significant changes in treatment uptake in the eight high-burden states that received the intervention compared to the control states from 2008-2018, policymakers can learn from the results of this intervention and develop policies that can increase diarrheal treatment uptake and invest in more comprehensive analysis of program results. This study indicates the importance of evidence-based policymaking decisions and the need to pressure-test policies before implementation. Consequently, policymakers should consider allocating the limited resources and money towards developing programs that have been tested and proven to be effective.

Though no statistically significant changes in treatment uptake were found due to the program, additional research can be conducted to better understand why there were no statistically significant changes in uptake. Implementation of the program may not have been suitable for the specific context of the program period and future research can also further explore which contexts could be suitable for appropriate implementation of the program.

Overall, policymakers can learn from the results of this intervention and develop policies that can increase diarrheal treatment uptake and increase investments towards more rigorous methods in evaluating efficacies of programs.

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Appendix:

S.1 Stata code

S.2. Hausman test

S.3. Removed fixed effects

S.4 Likelihood Ratio (LR Test)

S.5 Odds of odds ratio interpretation rationale

S.1. STATA code

Below outlines the code to append the NDHS 2008 and 2018 datasets and how variables were created and run in Models #1-#4.

Appended dataset:

```
use "/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR7BFL 2018 appending.DTA"

describe sstate

view sstate

use "/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR7BFL 2018 appending.DTA"

generate year=1

tab sstate

tab h38

tab h11

describe h11

save "/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR7BFL 2018 appending.DTA"

"/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR53FL 2008 appending .DTA"

tab sstate

generate year=0

save "/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR53FL 2008 appending .DTA"

append using "/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR7BFL 2018 appending.DTA""
```

```
tab year

save "/Users/cathy.xiang28/Box/DGHI Pilot Summer Internship/Cathy Xiang/NGKR53FL
Appended 2008,2018.dta"

tab sstate

tab h11

tab h11 year

generate treatment_state=0

describe treatment_state

describe sstate

tab treatment_state

replace treatment_state=1 if sstate==90

replace treatment_state=1 if sstate==110

replace treatment_state=1 if sstate==130

replace treatment_state=1 if sstate==290

replace treatment_state=1 if sstate==100

replace treatment_state=1 if sstate==30

replace treatment_state=1 if sstate==360

replace treatment_state=1 if sstate==330

tab treatment_state

//Generate interaction term

gen interaction = year * treatment_state
```

Models code:

/Zinctx Models1-4

//Model 1 (Baseline)

logit zinctx year treatment_state interaction i.sstate if nmis==0, or vce(cluster sstate)

//Model 2 (Individual)

logit zinctx year treatment_state interaction b8 b4 i.sstate if nmis==0, or vce(cluster sstate)

//Model 3 (Individual and Household)

logit zinctx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare i.sstate if nmis==0, or vce(cluster sstate)

//Model 4 (Individual, Household, and Comunity)

logit zinctx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare DPT_comm v102 i.sstate if nmis==0, or vce(cluster sstate)

//Orstx Models1-4

logit orstx year treatment_state interaction i.sstate if nmis==0, or vce(cluster sstate)

logit orstx year treatment_state interaction b8 b4 i.sstate if nmis==0, or vce(cluster sstate)

logit orstx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare i.sstate if nmis==0, or vce(cluster sstate)

logit orstx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare DPT_comm v102 i.sstate if nmis==0, or vce(cluster sstate)

//Zincandorstx Models1-4

logit zincandorstx year treatment_state interaction i.sstate if nmis==0, or vce(cluster sstate)

logit zincandorstx year treatment_state interaction b8 b4 i.sstate if nmis==0, or vce(cluster sstate)

logit zincandorstx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare i.sstate if nmis==0, or vce(cluster sstate)

logit zincandorstx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare DPT_comm v102 i.sstate if nmis==0, or vce(cluster sstate)

//Zincororstx Models1-4

logit zincororstx year treatment_state interaction i.sstate if nmis==0, or vce(cluster sstate) logit zincororstx year treatment_state interaction b8 b4 i.sstate if nmis==0, or vce(cluster sstate)

logit zincororstx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare i.sstate if nmis==0, or vce(cluster sstate)

logit zincororstx year treatment_state interaction i.v190 i.v149 b8 b4 difficultyseekingcare DPT_comm v102 i.sstate if nmis==0, or vce(cluster sstate)

S.2. Hausman test

Based on the results of the Hausman test, because all four outcome variables had a prob> chi2 of 0.00, the null hypothesis that there is no statistical difference between fixed versus random effects can be rejected. As a result, the fixed effect model with state fixed effects should be used instead of the random effects model.

S.3. Removed fixed effects

Treatment sought	Zinc				ORS			
	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)
Ratio of Odds Ratio								
Year	54.42 (23.12, 128.09) **	54.41 (23.10, 128.13) **	53.59 (22.93, 125.25) **	49.08 (21.19, 113.70) **	1.76 (1.16, 2.67) **	1.76 (1.16, 2.67) **	1.73 (1.14, 2.63) *	1.60 (1.08, 2.38) *
Treatment_states	1.06 (0.22, 5.02)	1.06 (0.22, 5.03)	1.07 (0.24, 4.86)	1.11 (0.24, 5.00)	1.11 (0.67, 1.83)	1.11 (0.67, 1.82)	1.13 (0.76, 1.70)	1.18 (0.81, 1.70)
Interaction (Treatment Effect)	1.16 (0.20, 6.69)	1.16 (0.20, 6.69)	1.16 (0.21, 6.40)	1.12 (0.21, 6.00)	1.01 (0.52, 1.97)	1.01 (0.52, 1.97)	0.98 (0.49, 1.97)	0.95 (0.48, 1.87)

Treatment sought	Zinc and ORS				Zinc or ORS			
	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)	Model 4 (95% CI)

Ratio of Odds Ratio								
Year	97.51 (27.41, 346.92) **	97.28 (27.36, 345.94) **	95.55 (26.85, 340.03) *	86.99 (24.82, 304.90) *	2.38 (1.55, 3.64) **	2.38 (1.55, 3.65) **	2.36 (1.53, 3.66) **	2.18 (1.43, 3.30) **
Treatment_states	1.25 (0.28, 5.62)	1.25 (0.28, 5.64)	1.24 (0.28, 5.51)	1.29 (0.29, 5.73)	1.10 (0.66, 1.85)	1.10 (0.66, 1.84)	1.14 (0.76, 1.72)	1.19 (0.82, 1.72)
Interaction (Treatment Effect)	1.00 (0.16, 6.16)	1.01 (0.16, 6.16)	1.01 (0.17, 5.99)	0.98 (0.17, 5.73)	1.02 (0.53, 1.97)	1.02 (0.53, 1.97)	0.99 (0.51, 1.92)	0.96 (0.51, 1.80)

When the “sstate” variable is removed from the model to remove state fixed effects, no statistical significance was found in treatment uptake across all four outcomes.

S.4. Likelihood Ratio (LR) Test

Based on the results of the LR test, there was no statistical significance between Model 1 and Model 2 for the zinc, ORS, zinc and ORS, and zinc or ORS outcomes. However, there was statistical significance between Model 2 and Model 3, and Model 3 and Model 4 across all four outcome variables.

S.5 Odds of odds ratio interpretation rationale

Equation:

$$Logit(Treatment\ Uptake_{ij}) = \beta_0 + (\beta_1 \times Intervention\ State_{ij}) + (\beta_2 \times Year_i) + (\beta_3 \times Intervention\ State_{ij} \times Year_i)$$

Difference in difference:

2008, control: $logit(p) = \beta_0$

2018, control: $logit(p) = \beta_0 + \beta_2$

2008, intervention: $logit(p)c\ \beta_0 + \beta_1$

2018, intervention: $logit(p) = \beta_0 + \beta_1 + \beta_2 + \beta_3$

Two differences:

Δcontrol$_{2018\text{-}2008}$= β_2

Δintervention$_{2018\text{-}2008}$= $\beta_2 + \beta_3$

Δdifference in difference=β_3

Equation:

$$\left[\log\left(odds_{intervention,2018}\right) - \log\left(odds_{intervention,2008}\right)\right] - \left[\log\left(odds_{control,2018}\right) - \log\left(odds_{control,2008}\right)\right]$$

$$\log\left(\frac{\mathrm{odds}_{intervention,2018}}{odds_{intervention,2008}}\right) - \log\left(\frac{odds_{control,2018}}{odds_{control,2008}}\right)$$

$$= \log\left(\frac{\frac{odds_{intervention,2018}}{odds_{intervention,2008}}}{\frac{odds_{control,2018}}{odds_{control,2008}}}\right)$$