Can informal health providers help improve health?
Experimental evidence from Nigeria

Pedro Carneiro, Yoonjei Michell Dong, Sanghmitra Gautam, Marcus Holmlund

December 2020

Abstract: This paper presents experimental evidence from a cluster-randomized controlled trial evaluating the effectiveness of involving non-traditional health services providers in malaria prevention and treatment in Southern Nigeria. We generate three main empirical results. First, household knowledge on malaria can be improved by involving community health workers and training drug retailors. At the same time, higher knowledge on malaria does not necessarily lead to higher preventive nor better care-seeking activities. While there is limited evidence on better prevention nor care-seeking behavior, we generally observe lower malaria prevalence among children in wards in which drug retailors were trained and subsidized. Our study tries to understand the potential mechanism by conducting heterogeneity analyses. We find that primary health facilities in Nigeria differ in terms of their quality at baseline and the intervention had higher impact in wards with better quality primary health facility. Our finding suggests that the quality of formal sector is also important for the effectiveness of informal health providers, and thus the complementary effect between non-traditional health workers and the existing public health system. Besides, we find heterogeneous impact by wealth status of households, which suggests that financial constraints prevent poor households from translating their improved knowledge into behaviors. While the project increased malaria-related knowledge for all treated households, only non-poor households were able to translate this knowledge into improved care-seeking behaviors and better health outcomes.

Keywords: malaria; informal health providers; public health system; Nigeria; randomized controlled trial

1. Introduction

Poor people are less likely to seek formal health care services (Dupas 2011). For instance, the typical response of poor households with symptoms of malaria is to self-diagnose and buy over-the-counter medication, instead of seeking care from formal health care system (Cohen et al. 2011). Lack of access to formal health services stems from both the demand and supply side constraints. On the one hand, poor people are reluctant to seek care from formal health facilities due to perceived irregularity of services, long waiting times, high user fees, and transportation costs (Gertler et al. 1987; Ogunfowokan and Mora 2012). On the other hand, increasing demand for formal health care cannot necessarily be a solution. Studies show that the quality of medical advice they receive from public health facilities are inadequate. In Delhi, a doctor spends on average only 3.5 minutes with a patient and performs less than one examination procedure (Das et al. 2008).

In response to the limited access to formal health care, the majority of households in developing countries seek health care services from informal health providers. In Nigeria, drug vendors are the first source of treatment where people seek care from when they are sick (DHS 2013). Informal providers are preferred since they have flexible working hours, geographically closer and offer more rapid service (World Bank 2015). At the same time, the quality of health services provided by informal health providers is controversial, especially since they have not received formal medical training. (Das and Hammer 2014).

In this paper, we try to answer the question if increasing access to informal health providers can improve health of households in developing countries. We use cluster-randomized controlled trial to evaluate the effectiveness of involving non-traditional health services providers in malaria prevention and treatment in Southern Nigeria. We first identify two important informal health providers in the region – community-directed distributors (similar to community health workers) and patent medicine vendors. Then, we divide the sample into four study arms – (i) community-directed distributors; (ii) patent medicine vendors; (iii) joint treatment arm; and (iv) control arm. This set-up allows us to answer several questions regarding the access to and quality of health care services in developing countries. First, we examine the impact of informal health providers in general. Second, we examine the relative and joint effectiveness between the two different informal health services providers. We address the issue of multiple inference by creating indices

following Anderson (2008) and using a family-wise error rate (Romano and Wolf 2005). The extensive survey instruments allow us to also understand the heterogeneous treatment effect by quality of formal health services within the village as well as household's asset index.

We generate three main empirical results. First, household knowledge on malaria can be improved by involving community health workers and training drug vendors. Across all treatment arms, malaria-related knowledge of households has increased by approximately 0.2 standard deviations. At the same time, higher knowledge on malaria does not necessarily lead to higher preventive activities or better care-seeking behavior. While there is limited evidence on better prevention or care-seeking behavior, we generally observe lower malaria prevalence among children in treatment wards.

Our study tries to examine the causal chain between improved knowledge and reduction in malaria by conducting heterogeneity analyses. We find that primary health facilities (PHFs) in Nigeria differ in terms of their quality and the intervention had higher impact in wards with better quality PHFs, which shows the complementary effect between non-traditional health workers and the existing public health system. Besides, we find heterogeneous impact by wealth status of households, which suggests that financial constraints prevent poor households from translating their improved knowledge into behaviors. While the project increased malaria-related knowledge for all treated households, only non-poor households were able to translate this knowledge into behaviors and better health outcomes. This finding suggests the need for a more reliable supply chain for any intervention aiming to extend primary healthcare services.

This paper makes an important contribution to a growing literature that estimates the returns to care in the formal sector. Existing studies show that limited access to formal care leads to prolonged illness which also affects labor supply of household members (Adhvaryu and Nyshadham 2015, 2017). At the same time, Godlonton and Okeke (2016) find that a large shift from informal to formal health care, following a ban on informal health providers, did not increase health of newborns mainly due to low quality of formal care. Our results are largely consistent with previous literature, but we advance the discussion by showing that the quality of formal sector is also important for the effectiveness of informal health providers, and thus the complementary effect between non-traditional health workers and the existing public health system.

This study also links to a broad literature in economics on how information impact health care decisions in developing countries (Dupas 2011a; Fitzsimons et al. 2016; Jalan and Somanathan 2008; Kremer and Miguel 2007; Meredith et al. 2013).[1] In our study, we find that supply-side interventions were able to improve malaria-related knowledge of households, but the improved knowledge translated into better care-seeking behaviors only for non-poor households. This shows that financial constraints prevent poor households from translating their improved knowledge into behaviors.

Finally, our paper makes new contributions to the existing literature in public health. We provide the first experimental evidence about the effectiveness of community health workers and patent medicine vendors in the prevention and treatment of malaria. There is little evidence around the effectiveness of community health workers and private-sector drug retailors in malaria control. (Detailed discussion on these literatures is presented on Appendix A.) Our findings provide important policy guidance on how to design future malaria program based on the experimental evidence.

The remainder of the paper proceeds as follows. Section 2 describes the background and intervention, Section 3 describes the location and study design, and Section 4 explains the data collected and empirical strategy. Section 5 reports the main findings, and Section 6 discusses the potential mechanism. Section 7 concludes.

2. Background and Intervention

2.1. Malaria in Nigeria

Malaria is the leading health burden in Nigeria and is the first-ranking cause of premature death throughout the past decades.[2] Though only 2% of the world's population lives in the country, Nigeria accounts for 27% of global malaria cases (Word Malaria Report, 2017). The 2015 Nigeria

[1] Dupas (2011a) shows that provision of age-disaggregated information on HIV prevalence rates decrease risky sexual behavior among girls in Kenya. Jalan and Somanathan (2008) find that the quality of drinking water improved by simply informing households of their water quality. Also, Fitzsimons et al. (2016) find that improving mother's knowledge on child health changes household decision to improve child's health including increased labor supply. On the other hand, Kremer and Miguel (2007) find that an educational campaign had little impact on the take-up of deworming medicine in Kenya. Similarly, Meredith et al. (2013) find no impact of information about health risk on the take-up of preventive health products in Kenya, Guatemala, India and Uganda.

[2] http://www.healthdata.org/results/country-profiles

Malaria Indicator Survey reports that 27 percent of children age 6-59 months were tested malaria positive by microscopy. In addition to being an important public health problem, malaria also has negative socioeconomic impacts at both macro and micro levels (Sachs and Malaney, 2002). The economic cost of malaria in Nigeria has been estimated to be in excess of 13% of the country's GDP (Jimoh et al. 2007). The economic cost of malaria not only stems from the direct costs to control and treat malaria, but also due to malaria-related productivity losses. Dillon, Friedman, and Serneels (2014) find that a program offering workplace malaria testing and treatment to sugarcane plantation workers in Adamawa State increases earnings by about 10% in the following weeks.

Despite high volumes of funding to control malaria, there has been limited achievement in Nigeria to combat malaria. In order to increase coverage of malaria prevention and effective treatment, the US$180 million World Bank-assisted Malaria Control Booster Project (MCBP) became effective in May 2007. The MCBP was implemented with objectives of (i) ensuring that the target population in the project states have access to, and utilize, a well-defined set of Malaria Plus Package interventions (which includes a set of interventions aimed at scaling-up preventive measures as well as diagnostic and treatment services related to malaria) and (ii) strengthening Federal- and State-level ability to manage and oversee the delivery of these interventions. An additional credit of US$100 million was approved in June 2009 to respond to the then recently updated National Malaria Strategy, specifically to the move towards universal coverage of the population with key malaria prevention and treatment interventions and the greater emphasis placed on diagnostics and health systems development.

2.2. Community and Private-Sector Based Interventions

Two new interventions were proposed under the additional financing in 2009 to complement the delivery of malaria services through public primary healthcare facilities. These are: (i) Community-Directed Interventions, in which Community-Directed Distributors (CDDs) are trained to provide malaria control services to members of their extended families; and (ii) training Patent Medicine Vendors (PMVs) – private drug retailers – in diagnosis of malaria and the appropriate sale of subsidized Artemisinin-based Combination Therapies (ACTs). The CDD and PMV interventions were implemented on a pilot basis from April 2013 to March 2015. We discuss in more detail about the two interventions below:

1. Community-Directed Distributors: CDDs were selected from their community to serve as health workers for their extended family members. They were trained on preventive actions, diagnosis using rapid diagnostic tests (RDTs) and home management of malaria with ACTs. Also, RDTs and ACTs were provided for free to CDDs through public health facilities. CDDs were selected from each community based on (i) their likelihood to stay in their community, (ii) ability to read and write, and (iii) relevant experiences. In particular, community volunteers that served in the River Blindness Onchocerciasis Project were preferred, as they had been exposed to a project with a similar delivery model. A total of 4,176 CDDs were selected for the training in Anambra State, approximately 30 CDDs from each primary health center catchment area, and 686 CDDs were sampled for the survey, an average of five per political ward .

2. Patent Medicine Vendors: Selected PMVs were trained on symptomatic diagnosis of malaria and malaria treatment. They were provided with ACT at a subsidized rate through the intervention, with the intention that the subsidy would be passed through to the end-user. The Anambra State MCBP team cooperated with the PMV association to select PMVs to be trained for the project. There is a local PMV association coordinator in each local government area (LGA), and this coordinator was responsible for selecting PMVs in their LGA. In the end, a total of 979 PMVs were selected from Anambra State, an average of seven per political ward as per the intervention design (not all PMVs operating in the state were selected for the intervention).

Location and Study Design

2.3. Location

The study was carried out in 280 wards in Anambra, a Southern state of Nigeria. Based on population representative data from Living Standards Measurement Survey (LSMS), Anambra has a 136,352 Naira annual consumption per capita (373 US Dollars), which is above the national average of 110,984 Naira. In Nigeria, malaria transmission is perennial, with peaks during the wet season from April to September. Malaria prevalence is relatively low in the south-south and the south-east region of Nigeria, especially in Anambra state where the risk of testing positive to parasitemia is below 20%. Population representative data from the 2015 Nigeria Malaria Indicator Survey (MIS) shows a malaria prevalence of 10% among children under five in Anambra state, which is below the national average (27%).

2.4. Study Design

The study uses a cluster-randomized controlled trial design to test whether the CDD and PMV interventions, jointly or in isolation, have a causal impact on key outcomes of interest. Randomization ensures that households in the control and different treatment groups have, on average, comparable background characteristics. Thus, in the absence of the program, on average, they would likely have comparable outcomes. By comparing outcomes between the treatment and control group, we can therefore estimate the effect of the program we are testing.

The goal of the randomization, therefore, is to create four groups within the study area. In each of three of these, a different combination of the interventions – CDD only, PMV only, or CDD+PMV – are tested, while the fourth would act as a control group to understand what happens when neither the CDD nor the PMV intervention is implemented. For the impact evaluation, the ward was chosen as the appropriate level of randomization, to maximize the likelihood that (i) the different study arms are broadly spread across the different areas of the state and (ii) there is some distance between the areas in the different study arms, which protects against spillovers or contamination across study arms.

The ward was also selected as the unit of intervention for PMV intervention, meaning that if a ward was assigned either to the PMV or the CDD+PMV study arms all PMVs within that ward were eligible for inclusion in the intervention. For CDD, the primary health care facility catchment area was selected as the unit of implementation, due to the need to link these newly trained community-level providers to a reference facility.

In wards with only one public primary health facility, that facility's catchment area was selected by default. In wards with two or more public primary health facilities, one of these was selected at random. The list of health facilities was based on a listing completed in 2011. All wards in Anambra State were found to have at least one functioning public health facility, and so all wards were eligible for inclusion in the impact evaluation. Based on sample size calculations carried out by the research team, it was determined that 280 out of a total of 327 wards would need to be included in the study in order to detect the anticipated causal impacts of the CDD and PMV interventions.

Randomization was carried out by the Anambra State Malaria Control Booster Project and the research team using the following procedure:

Wards were assigned to one of the three treatment groups or the comparison groups using a program written for the statistical analysis software Stata. The basis for this random assignment was a random number, or "seed", selected by the Anambra State Malaria Control Booster Project team. The randomization was stratified by senatorial district so that Anambra North, Anambra Central, and Anambra South would each have the same (or very similar) numbers of wards assigned to each study arm, with the total number of study wards proportional to the number of wards in each senatorial district.[3]

3. Data and Empirical Strategy

3.1. Data Collection

In order to measure the impact of the project, we conducted two rounds of data collection – baseline and endline. The baseline survey was conducted from January to April 2013 prior to project implementation, and the endline survey was conducted approximately 24 months later, between December 2014 and January 2015. In both rounds of the survey, data were collected from both the demand and supply-side actors including household, community, patent medicine vendor (PMV), community-directed distributor (CDD), public primary healthcare facility (PPHF), and public primary healthcare facility clinical worker. The household survey collected a wide variety of information on the households including demographic information, consumption and asset, housing characteristics, malaria-related knowledge, individual's health-seeking behavior, and a health module (including rapid diagnostic test for malaria, blood tests for anemia, and anthropometric measurements). In order to ensure that the survey collected information on a sufficient number of children under five and women of reproductive age, only households with (i) a mother with children under 5 or (ii) a woman of reproductive age were eligible to participate in the survey. In addition, community-level data was collected to supplement the household survey and to control for important community-level variations. As primary health facilities (PHFs) play a major role in malaria treatment, workers from each PHFs were interviewed on (i) facility characteristics, (ii) malaria-related services provided by the facilities, and (iii) malaria-related

[3] For further detail on the study design, please refer to DIME (2014).

training and knowledge of health facility workers. Lastly, CDDs and PMVs were asked about (i) general demographic characteristics, (ii) community work experience, (iii) health training experience, (iv) malaria-related knowledge and quality of care and (v) drug procurement and availability. Our total sample consists of approximately 4,200 households per wave across 280 wards in Anambra State.

3.2. Baseline Characteristics

Table 1 shows the baseline characteristics by treatment arms from the data collected before project implementation.

In order to test balance in baseline characteristics across treatment arms, we regress each covariate denoted Var_{ijs} for individual *i*, ward *j*, and senatorial district *s* on three dummy variables indicating each treatment arm – CDD, PMV, and CDD+PMV. The following regression is used to test the baseline balance:

$$Var_{ijs} = \beta_1 CDD_j + \beta_2 PMV_j + \beta_3 (CDD + PMV)_j + \gamma_s + \varepsilon_{ijs}$$

On column (5), we report the p-value on the joint test $\beta_1 = \beta_2 = \beta_3 = 0$.

Table 1 confirms that the randomization was generally successful in creating study groups of clusters which are, on average, similar in terms of (i) household head characteristics; (ii) household socio-economic status; (iii) household malaria-related knowledge; (iv) malaria prevention activities; (v) care-seeking behavior; and (vi) malaria prevalence in vulnerable groups; and (vii) health status for children under five. The unit of "cluster" used in this study is the political ward. As shown in Table 1, there are some minor imbalances between the treatment and control groups in terms of three variables – marital status, family size and consumption. In all of our analyses, we control for the baseline value of these three variables.

According to the baseline sample, 23% of the households in the control sample are headed by female, and household heads in the sample are overwhelmingly Christian (95%). Also, 74% of household head in the control sample are literate and 39% of the household heads have completed secondary school. The average age of household head is 52, 25% of the household heads are involved in the agricultural sector, 12% are involved in wage employment, and 41% are self-

employed. 80% of households in the sample have access to improved water source and 81% own a toilet.

Household's malaria-related knowledge is comparable across study arms, while households living in CDD treatment arms have marginally higher behavior index which means that they are more likely to engage in malaria prevention activities.[4] According to the biomedical test conducted during the baseline survey, 6% of children under five were tested malaria-positive, 49% were anemic, and 32% were stunted.[5]

Table 1: Baseline Household Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
	Regression Coefficients and Standard Errors					
	Control Mean/SE	CDD Mean/SD	PMV Mean/SD	CDD+PMV Mean/SD	Joint Test p-value	N
Household Head Characteristics						
% female-headed household	0.225 {0.418}	-0.025 (0.026)	-0.034 (0.023)	-0.015 (0.023)	0.767	3782
% household head married	0.774 {0.418}	0.097*** (0.025)	0.090*** (0.024)	0.047* (0.026)	0.099*	3632
% household head Christian	0.953 {0.212}	-0.03 (0.019)	-0.027 (0.021)	-0.01 (0.020)	0.664	3717
% household head literate	0.738 {0.440}	0.01 (0.036)	0.012 (0.036)	0.025 (0.033)	0.883	3735
% completed secondary school	0.393 {0.489}	-0.048 (0.038)	-0.019 (0.038)	-0.015 (0.039)	0.679	3741
Age	51.85 {16.37}	-1.786 (1.141)	-0.873 (1.252)	-0.818 (1.213)	0.608	3704
% working in agriculture	0.251 {0.434}	0.033 (0.049)	-0.008 (0.049)	-0.01 (0.050)	0.599	3583
% wage employed	0.121 {0.327}	0.0041 (0.020)	0.001 (0.021)	-0.001 (0.020)	0.968	3583
Household Socio-economic Status						
Yearly income per capita (in dollar)	1008.2 {1919.3}	-34.73 (150.0)	-6.818 (167.9)	-201.8 (139.5)	0.326	4153
Yearly consumption per capita (in dollar)[6]	633.4 {543.7}	6.789 (54.990)	-85.48* (47.350)	20.18 (51.270)	0.059*	4153

[4] Section 4.4 documents how we constructed the knowledge and behavior indices.
[5] According to 2013 Nigeria Demographic Health Survey, 37% of children under five in Nigeria were stunted, 18% of children were wasted, and 29% of children under five were underweight.
[6] This is a limited measure of consumption including consumption on food, transportation, health and housing.

Family size	4.425 {2.338}	0.303* (0.177)	0.286* (0.167)	-0.042 (0.176)	0.070*	4153
% using improved water source	0.802 {0.398}	0.0115 (0.042)	-0.019 (0.047)	-0.025 (0.043)	0.7	4119
% owning toilet	0.77 {0.421}	-0.002 (0.046)	-0.011 (0.046)	-0.026 (0.047)	0.886	4153
Malaria-related						
Knowledge Index	0.000 {1.00}	0.125 (0.092)	0.000 (0.092)	0.086 (0.083)	0.458	4153
Behavior Index	0.000 {1.00}	0.189* (0.101)	0.0633 (0.102)	0.011 (0.102)	0.226	4153
% RDT-positive for children under five	0.057 {0.232}	0.024 (0.028)	-0.006 (0.024)	-0.026 (0.024)	0.111	1518
% anemic	0.49 {0.501}	-0.065 (0.063)	-0.075 (0.064)	-0.058 (0.062)	0.954	1516
Stunting	0.328 {0.471}	0.086 (0.062)	0.026 (0.063)	0.015 (0.055)	0.517	667

Note: Difference between treatment and control was calculated based on an estimate of Ɓ1 from the equation Var=Ɓ0 + Ɓ1* Treatment + randomization strata + Ɛ where Treatment is a dummy for treatment status and randomization strata is dummies for senatorial district. The standard errors are robust and clustered at the ward-level. The p-value in the table is derived from a two-sided t-test with the null hypothesis of Ɓ1= Ɓ2= Ɓ3=0. ***, **, * indicate significance at, or below, 1, 5, 10 percent respectively.

3.3. Empirical Strategy

Our empirical strategy is to causally estimate the average treatment effect of a ward being assigned to either CDD, PMV or CDD+PMV study arm, using a simple reduced-form specification. We estimate the effect of each treatment group using the following specification where we regress an outcome variable denoted Var_{ijs} for individual i, ward j, and senatorial district s on three dummy variables indicating each treatment arm – CDD, PMV, and CDD+PMV. X_{js} is a vector of ward-level control variables measured at baseline. The control variables include basic household characteristics, including marital status of household head, number of family members, and log of consumption amount, and baseline value of the respective dependent variable. All regressions include senatorial-district fixed effects γ_s because the randomization was stratified at this level, and standard errors are clustered at the ward level.

$$Var_{ijs} = \beta_1 CDD_j + \beta_2 PMV_j + \beta_3 (CDD + PMV)_j + X_{js}\delta + \gamma_s + \varepsilon_{ijs}$$

In this section, we report the treatment effects two years after project implementation using the endline data collected between December 2014 and January 2015. We analyze the impact of the intervention by analyzing the list of outcomes discussed in the following section.

3.4. Outcome of Interest

We examine the impact of the MCBP project on outcomes of interest along the causal chain, including household's malaria-related knowledge, prevention activities, health care-seeking behaviors, and malaria prevalence. By improving malaria-related service delivery through CDDs and PMVs, the interventions are designed to first improve malaria-related knowledge among households. During the household survey, we ask six key questions related to malaria. These include questions on (i) the main cause of malaria as mosquito; (ii) danger signs of malaria as fever; (iii) most vulnerable group to malaria as children under five and pregnant women; (iv) best protection against malaria as mosquito net; (v) best treatment for malaria as ACT; and (vi) knowledge on RDT. In order to understand the overall treatment impact on knowledge, we construct a knowledge index following Anderson (2008) which is a weighted mean of standardized outcomes.

We believe that improved malaria-related knowledge would translate into better prevention activities and health care-seeking behaviors. We measure prevention activities by examining the mosquito net ownership of households and whether household members slept under mosquito net the night prior to the survey. We create a behavior index using the following four variables – (i) percentage of households with at least one mosquito net; (ii) percentage of households sprayed dwelling in the past 12 months; (iii) percentage of household members sleeping under a net is higher than 50; (iv) percentage reporting protection used against malaria as mosquito net. Additionally, we measure health care-seeking behaviors by looking at the percentage of individuals taking ACT when they had fever/malaria.[7]

[7] In Appendix Table 3, we report health care-seeking behaviors by looking at (i) the percentage of individuals consulting with health professionals when they had fever; (ii) percentage of individuals getting diagnosed using RDT or microscopy; and (iii) percentage of individuals taking ACT when they had fever/malaria.

Ultimately, we aim to reduce malaria prevalence in the region covered by the project. During the household survey, we conducted RDT tests among children under five and children 5-12. We use this measure to examine the impact of the intervention on malaria reduction.

4. Empirical Results

As shown in Table 2, households in all three treatment arms have better malaria-related knowledge compared to households in control arm. Knowledge index in CDD treatment arm is 0.17 standard deviation higher than that of the control group, and knowledge indices in PMV and CDD+PMV treatment arms are 0.26 standard deviation higher than that of the control group. We find overall higher treatment effect in the PMV arm compared to the CDD arm. The larger treatment impact for PMV arms suggests that PMVs are not only interested in making profits by selling drugs, but they perceive themselves as "health workers" and derive some intrinsic motivation from this. Indeed, more than half of the PMVs (53%) report that they have provided health services in addition to their regular PMV work in the past 3 months prior to the follow-up interview. This finding suggests that household knowledge can be improved from training the private-sector drug retailors who are usually the first point of contact to buy over-the-counter medicine in case of fever/malaria.

Even though households in the treatment wards have better malaria-related knowledge, there is no significant impact on malaria prevention behaviors. The behavior index shows that there is little impact of the intervention on prevention behaviors in general. The lack of impact on malaria prevention behavior is not surprising since our intervention did not specifically target malaria prevention. Besides, Appendix Table 3 shows that there is only a marginally significant impact on care-seeking behaviors for children in the PMV arm and lack of impact for children in the CDD arm. Children aged 5-12 living in PMV and CDD+PMV arms are more likely to take ACT when they have malaria compared to those living in the control arm (Full regression results included in Appendix Table 3).

The ultimate goal of the CDD and PMV interventions is to reduce malaria prevalence. As shown in Table 2, children under 5 in PMV treatment arm have lower malaria prevalence by 4 percentage point compared to children under 5 in control arm. This translates into a malaria reduction by 42 percent. Also, children between 5 and 12 years of age in CDD and CDD+PMV treatment arms

have lower malaria prevalence compared to children between 5 and 12 years of age in control arm by 6 and 7 percentage points (or a malaria reduction by 32 percent and 37 percent), respectively. This is a large decrease especially given the limited changes in health-seeking behaviors.

Table 2: Main Outcome

	(1) Knowledge	(2) Behavior	(3) ACT treated	(4) RDT under five	(5) RDT 5-12
CDD	0.171**	0.004	0.030	-0.009	-0.061*
	(0.072)	(0.086)	(0.035)	(0.020)	(0.033)
PMV	0.257***	0.020	0.075*	-0.036**	-0.030
	(0.066)	(0.085)	(0.040)	(0.018)	(0.034)
CDD+PMV	0.263***	0.045	0.053	-0.013	-0.070**
	(0.065)	(0.076)	(0.038)	(0.021)	(0.030)
Observations	4,265	4,265	1,978	1,931	1,550
Control	YES	YES	YES	YES	YES
Strata FE	YES	YES	YES	YES	YES
Mean of dependent variable	-0.184	0.000	0.231	0.0854	0.186

Note: Data on RDT positive rate is collected from the biomedical test conducted during the endline survey. All regressions include village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.

The break in the causal pathway between knowledge and behavior suggests that the intervention was not sufficient to change the care-seeking behaviors of the households. At the same time, the lower malaria prevalence in the treatment arms suggests that there could be another mechanism, possibly on the supply-side, through which the intervention had an impact. Before examining the causal chain, we conduct multiple hypothesis testing in the next section to validate the overall impact of the project.

4.1. Multiple Hypothesis Testing

The results above suggest that we have significance in some indicators, while it is hard to say that the project had a significant impact overall. We are concerned that we are rejecting some of the hypotheses by chance since we are testing too many hypotheses. In order to solve this problem, we conduct multiple hypothesis testing following Anderson (2008) and Romano and Wolf (2005). As mentioned in the previous section, we first follow Anderson (2008) to two summary indices – knowledge and prevention– which is a weighted mean of several standardized outcomes.

Knowledge index includes household knowledge on (i) main cause of malaria; (ii) danger signs of malaria; (iii) vulnerable groups to malaria; (iv) best protection against malaria; (v) best treatment for malaria; and (vi) knowledge on RDT. Behavior index includes (i) percentage of households with at least one mosquito net; (ii) percentage of households that sprayed dwelling in the past 12 months; (iii) percentage of household members sleeping under a net is higher than 50; (iv) percentage reporting protection used against malaria as mosquito net. We also include RDT results for children under five and children 5-12.[8]

Using the four variables, we use Romano and Wolf (2005) method to calculate the corrected p-values that asymptotically controls for familywise error rate. As shown in Table 3, even after the multiple testing correction, all treatment arms have significant impact on improving household knowledge, and CDD and CDD+PMV treatment arms have marginally significant impact on reducing malaria prevalence.

Table 3: Multiple Hypothesis Testing

VARIABLES		(1) Knowledge	(2) Prevention	(3) RDT under five	(4) RDT 5-12
CDD treatment		0.166	0.012	-0.009	-0.061
		(0.070)	(0.085)	(0.020)	(0.033)
	naïve p-value	*0.019***	*0.887*	*0.681*	*0.052**
	corrected p-value	*0.089**	*0.881*	*0.673*	*0.089**
PMV treatment		0.256***	0.021	-0.036	-0.030
		(0.065)	(0.085)	(0.018)	(0.034)
	naïve p-value	*0.000****	*0.801*	*0.060**	*0.384*
	corrected p-value	*0.010****	*0.733*	*0.119*	*0.416*
CDD+PMV treatment		0.259***	0.048	-0.013	-0.070
		(0.064)	(0.076)	(0.021)	(0.030)
	naïve p-value	*0.000****	*0.533*	*0.450*	*0.017***
	corrected p-value	*0.010****	*0.623*	*0.426*	*0.069**
Observations		4265	4265	1931	1550

*Note: All regressions include village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies. Corrected p-values use Romano & Wolf test with 1,000 iterations.

[8] We do not include care-seeking behaviors due to small sample size and sample selection problem - questions related to care-seeking behaviors were only asked to individuals that suffered from fever/malaria in the past 4 weeks.

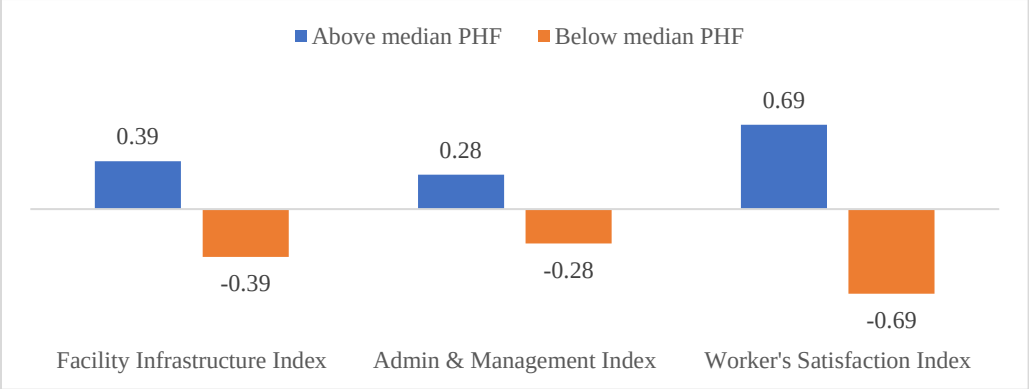
5. Heterogeneous Treatment Effects

5.1. Heterogeneity by Quality of Primary Health Facility

The intervention builds upon the existing public health system where quality varies widely. In particular, public health facilities act as the implementing agency through which trainings are provided and medicines are distributed to informal health providers. Research shows that there is a large variation in the quality of health facilities, which is one of the main barriers to better health outcomes in low-income countries (Das and Hammer 2014). The importance of quality of health facilities as well as the implementing agency has been found in many contexts (Das et al. 2017; Cameron et al. 2019).

During the baseline and endline data collection, we collected extensive information about the PHFs in our sample, and 280 PHFs in the Anambra State were divided into two groups based on their baseline characteristics on (i) quality of facility infrastructure; (ii) administrative and management quality; (iii) PHF worker's satisfaction score; (iv) health workers' malaria-related knowledge; and (v) community outreach activities. Using LASSO (least absolute shrinkage and selection operator) method, we identified 63 baseline PHF quality variables that best predict baseline malaria prevalence (list of variables in Appendix Table 2). Using generalized structural equation modeling (GSEM), we created a PHF quality index based on the selected baseline PHF quality variables and divided the 280 PHFs into above-median and below-median PHFs. Appendix Table 2 shows the difference between below- and above-median PHFs in terms of their characteristics. As shown in Figure 1, above-median PHFs have on average higher scores in terms of infrastructure index, administrative and management index, and PHF worker's satisfaction index.

Figure 1: PHF Quality



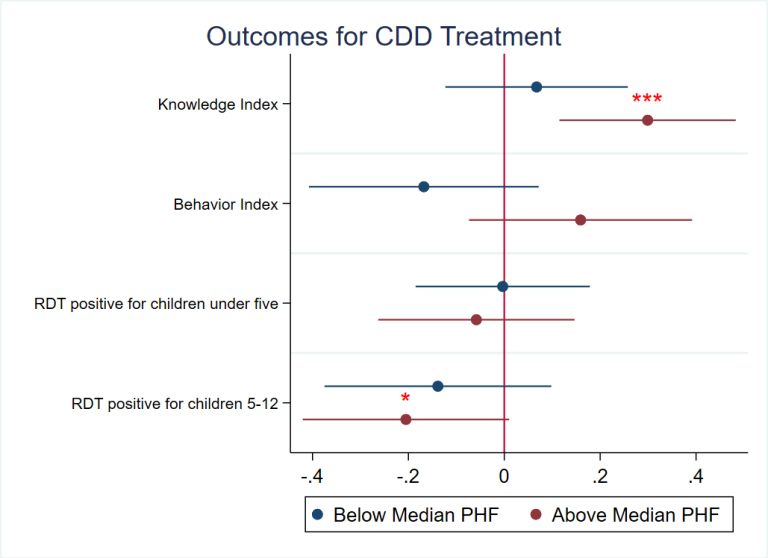
Since PHF quality is not randomly assigned across villages, one concern is that higher quality of PHF reflects better community infrastructure in general, and therefore, community characteristics in above-median PHF quality areas systematically differ from those in below-median PHF quality areas. In this case, we may falsely attribute differing effects by community characteristics as heterogeneous treatment effects by PHF quality. To address this problem, we examine if community characteristics differ between the two PHF quality groups. In Appendix Table 3, we confirm that communities with above-median PHF quality have similar community characteristics to those with below-median PHF quality. Also, in Appendix Table 4, we confirm that communities with better infrastructure do not necessarily exhibit higher treatment effect.

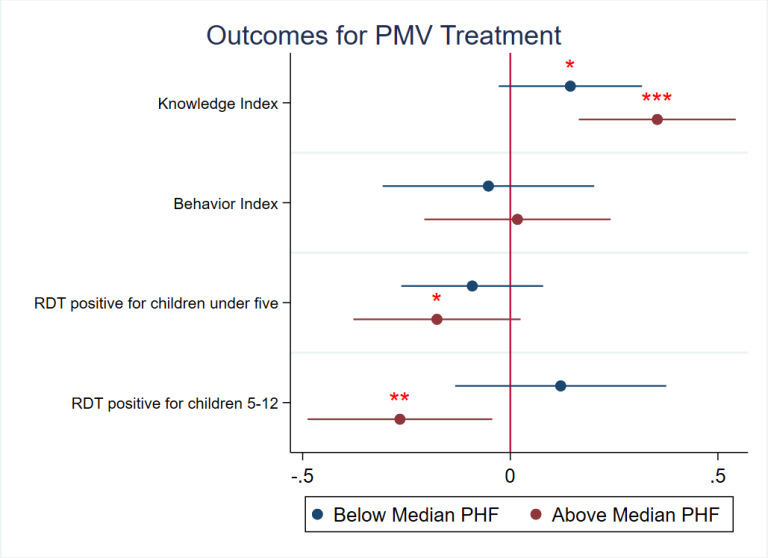
The large gap in PHF quality partly explains the reason for lack of impact in some of the treatment wards. As shown in Table 4, treatment households living in above-median PHF catchment areas have improved malaria-related knowledge and reduction in malaria prevalence, while we do not observe the treatment effects for households living in below-median PHF catchment areas. It may be surprising to see that PMV treatment effects also differ by PHF quality, since the PMVs were not administered by the health facilities. At the same time, majority of PMVs (79%) reported that they have referred customers with malaria to nearby health facility at baseline, and this result suggests that there is complementary effect between the informal (PMVs) and formal (PHFs) health providers.

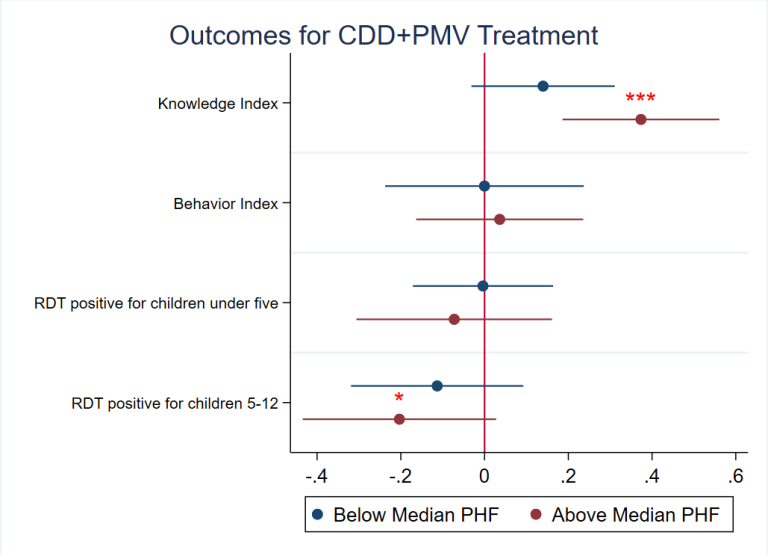
Table 4: Heterogeneity Treatment Effects by Primary Health Facility Quality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Low PHF	High PHF	Low PHF	High PHF	Low PHF	High PHF	Low PHF	High PHF
	Knowledge		Behavior		RDT under five		RDT 5-12	
CDD	0.037	0.278***	-0.155	0.148	-0.002	-0.026	-0.067	-0.077*
	(0.101)	(0.092)	(0.117)	(0.115)	(0.027)	(0.032)	(0.043)	(0.042)
PMV	0.116	0.378***	-0.032	0.036	-0.022	-0.057**	0.028	-0.104**
	(0.087)	(0.097)	(0.124)	(0.112)	(0.025)	(0.029)	(0.049)	(0.040)
CDD+PMV	0.130	0.380***	0.023	0.053	0.008	-0.035	-0.039	-0.068
	(0.083)	(0.097)	(0.109)	(0.103)	(0.027)	(0.031)	(0.040)	(0.049)
N	2,110	2,155	2,110	2,155	734	728	536	535
Control	YES	YES	YES	YES	YES	YES	YES	YES
Strata FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: All regressions include village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.


Outcomes for CDD Treatment
Knowledge Index
Behavior Index
RDT positive for children under five
RDT positive for children 5-12
***
*
-.4
-.2
0
.2
.4
Below Median PHF
Above Median PHF


Outcomes for PMV Treatment
Knowledge Index
Behavior Index
RDT positive for children under five
RDT positive for children 5-12
*
***
*
**
-.5
0
.5
Below Median PHF
Above Median PHF


Outcomes for CDD+PMV Treatment
Knowledge Index
Behavior Index
RDT positive for children under five
RDT positive for children 5-12
***
*
-.4
-.2
0
.2
.4
.6
Below Median PHF
Above Median PHF

5.2. Potential Mechanism

Overall, the results suggest that there is a break in the causal pathway at the household level, and thus a change in the supply-side potentially resulted in lower malaria prevalence among treatment households. In particular, we find that only households living in above-median PHF quality catchment areas were able to have higher malaria-related knowledge and lower malaria prevalence following the intervention. In this section, we examine why PHFs are important for the effectiveness of the interventions and explore the main obstacles faced by households in translating their improved knowledge into behaviors.

Drug availability

Higher quality PHFs may be able to better implement the intervention, and thus better stock and disburse malaria drugs to CDDs and PMVs. This may reduce the supply chain issues faced by many informal health providers working in developing countries. In order to test this hypothesis, we examine if the quality of PHFs is correlated with their performances related to the intervention, including the availability of malaria-related drugs.

Table 5 shows that above-median PHFs are more likely to report having ACT available following the intervention, while there is no impact on drug availability for below-median PHFs. This implies that the stock-out issues faced by CDDs and PMVs were more problematic for providers working in below-median PHF areas. (57% of CDDs and 24% of PMVs experienced at least one stock-out of ACT in the three months preceding the follow-up interview. Also, as shown in Appendix Table 7, only PMVs working in above-median PHFs are more likely to be aware of ACTs following the intervention.[9]) Stock-out issues in the Nigerian public primary health sector are a well-documented problem, and more reliable supply chains are needed for any intervention aiming to extend primary healthcare services to achieve its full potential in promoting accurate diagnosis and treatment of malaria.

[9] CDDs were introduced by the intervention, and thus we were not able to survey control CDDs. For this reason, it is impossible to compare the treatment effects on drug availability of CDDs between above-median and below-median PHF areas.

Table 5: Drug Availability by PHF Quality

	(1)	(2)
ACT&SP Drug Availability	**Above median PHF**	**Below median PHF**
CDD	0.551**	-0.058
	(0.229)	(0.261)
PMV	0.107	-0.406
	(0.229)	(0.261)
CDD+PMV	0.491**	-0.245
	(0.235)	(0.252)
Constant	-0.109	0.030
	(0.153)	(0.195)
Observations	133	131
R-squared	0.060	0.025

Heterogeneity by socioeconomic status

In addition, treatment impact may differ by households' wealth status as the program does not directly target poor households but benefits are passed through health providers. Previous literature shows that wealthier (or more educated) households are more likely to be aware of and utilize the new information, while poor households may not be able to enjoy the treatment effect especially if the subsidy is not high enough (Dupas 2011). In order to test this assumption, we examine if the treatment impact differs by household's socioeconomic status.

First, we check if poor households differ from non-poor households in where they seek care from. Regression results in Table 6 show that following the intervention, non-poor households are more likely to seek care from informal health providers. This is consistent with previous literature that more educated households are more likely to process and adopt the new information or technology (Dupas, 2011).

Table 6: Percentage seeking care from informal health providers

	(1) Total	(2) Poor	(3) Non-Poor
	Seeking care from informal health providers		
CDD	0.091*	0.024	0.183***
	(0.051)	(0.066)	(0.055)
PMV	0.085*	0.059	0.121**
	(0.050)	(0.061)	(0.060)
CDD+PMV	-0.008	-0.085	0.104*
	(0.045)	(0.055)	(0.059)
Constant	0.288*	0.160	0.436**
	(0.153)	(0.169)	(0.204)
Observations	1,747	949	779
R-squared	0.013	0.020	0.026

When we analyze the treatment impact in above median PHF quality areas by their wealth level, we find impact only among non-poor households. While treated households living in above-median PHF catchment areas experienced an increase in malaria-related knowledge, only non-poor households living in above-median PHF catchment areas had access to ACT when they had fever, and experienced reduction in malaria prevalence.

Table 7: Treatment Impact by Asset Index

	(1)	(2)	(3)	(4)	(5)	(6)
	Knowledge		ACT treated		RDT 5-12	
	poor	non-poor	poor	non-poor	poor	non-poor
CDD	0.376***	0.168	0.019	0.097**	-0.062	-0.121**
	(0.114)	(0.113)	(0.065)	(0.048)	(0.055)	(0.057)
PMV	0.403***	0.394***	0.021	0.217***	-0.059	-0.169***
	(0.118)	(0.109)	(0.068)	(0.066)	(0.056)	(0.060)
CDD+PMV	0.418***	0.367***	-0.014	0.175***	-0.034	-0.125*
	(0.124)	(0.105)	(0.071)	(0.063)	(0.053)	(0.063)
Observations	1,131	996	533	483	396	356
Control	YES	YES	YES	YES	YES	YES
Strata FE	YES	YES	YES	YES	YES	YES
Mean of dependent variable	-0.396	-0.120	0.216	0.183	0.180	0.243

Note: All regressions include village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.

This finding suggests that the intervention improved malaria-related knowledge for all households, but stock-out issues mentioned in the previous section prevented poor households from having access to ACT. On the other hand, non-poor households were able to translate their improved knowledge into better care-seeking behavior, have access to ACT and experience better health outcomes.[10] For this reason, the overall treatment effect is stronger for non-poor households.

6. Conclusion and Policy Implications

This study provides experimental evidence on involving two non-traditional health providers in the prevention and treatment of malaria. The results suggest that there is a break in the causal pathway between knowledge and behavior especially among poorer households. High levels of household-level knowledge on malaria prevention do not translate into high-levels of net use. While higher percentage of households in the treatment arms were treated with ACT when they had fever, the result is only significant for non-poor households. In both cases, this suggests further consumer education efforts are needed to change household behaviors and implies that there is another causal pathway through which the intervention reduces malaria prevalence in the treatment households.

At the same time, we find significantly higher treatment effects in areas with better quality of primary health facilities. The importance of quality of primary health facilities are recognized in many studies (Das and Hammer, 2014), and our study shows that they are also important when involving non-traditional health providers. This is mainly because these non-traditional health providers, including drug retailors and community health workers, refer their patients to nearby health facilities for complicated malaria. This suggests that non-traditional health providers should be regarded as complementary with rather than substituting the existing public health system.

Lastly, we find that drug stock-outs, a well-documented problem in Nigeria, prevented poor households from having access to subsidized drugs. At the same time, non-poor households were able to translate their improved knowledge into better care-seeking behavior and better health outcomes. This finding raises the external validity issue when the project is scaled up as there

[10] Even though stock-out issues were experienced among the treated providers, households were still able to buy ACTs from the market at unsubsidized price.

could be general equilibrium effects such as drug shortage associated with the scale of the project. This finding also suggests the need for a more reliable supply chains for any intervention aiming to extend primary healthcare services. Our study provides important policy implications for policy makers designing subsidies for essential health products especially in countries where supply chains are unreliable in the public health system.

References

Anderson, Michael L.. 2008. "Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects." Journal of the American Statistical Association, 103:484, 1481-1495.

Banerjee, Abhijit V., Rukmini Banerji, Esther Duflo, Rachel Glennerster and Stuti Khemani. 2010. "Pitfalls of Participatory Programs: Evidence from a Randomized Evaluation in Education in India." American Economic Journal: Economic Policy, American Economic Association, vol. 2(1), pages 1-30.

Björkman, Martina, Jessica Leight and Vandana Sharma. 2017. "Community Health Educators and Maternal Health: Evidence from a Randomized Controlled Trial." Working Paper.

Björkman, Martina, and Jakob Svensson. 2009. "Power to the People: Evidence from a Randomized Field Experiment on Community-Based Monitoring in Uganda." The Quarterly Journal of Economics, 124 (2): 735-69.

Cohen, Jessica Cohen, Pascaline Dupas and Simone Schaner. 2015. "Price Subsidies, Diagnostic Tests, and Targeting of Malaria Treatment: Evidence from a Randomized Controlled Trial." American Economic Review, American Economic Association, vol. 105(2), pages 609-45.

Das, Jishnu and Jeffrey Hammer. 2014. "Quality of Primary Care in Low-Income Countries". Annual Review of Economics.

Das, Jishnu, Jeffrey Hammer, and Kenneth Leonard. 2008. The quality of medical advice in low-income countries. The Journal of Economic Perspectives, 22(2), 93-114.

Dillon, A., Friedman, J., & Serneels, P. 2014. Malaria Infection, Health Information and Productivity: Experimental Estimates from Nigerian Sugarcane Cutters. *Centre for the Study of African Economies, University of Oxford.*

Dunsch, Felipe A.; Evans, David K.; Eze-Ajoku, Ezinne; Macis, Mario (2017) : Management, Supervision, and Health Care: A Field Experiment, IZA Discussion Papers, No. 10967, Institute of Labor Economics (IZA), Bonn.

Dupas, Pascaline. 2011a. "Do Teenagers Respond to HIV Risk Information? Evidence from a Field Experiment in Kenya." American Economic Journal: Applied Economics 3 (1), pp.1-36.

Dupas, Pascaline. 2011b. "Health Behavior in Developing Countries." Annual Review of Economics Vol. 3, pp. 425-449.

Dupas, Pascaline, and Jonathan Robinson. 2013. "Why Don't the Poor Save More? Evidence from Health Savings Experiments." American Economic Review, 103 (4): 1138-71.

Fearon, James, Macartan Humphreys and Jeremy Weinstein. 2009. "Can development aid contribute to social cohesion after civil war? Evidence from a field experiment in post-conflict Liberia." American Economic Review.

Fitzsimons, Emla, Bansi Malde, Alice Mesnard and Marcos Vera-Hernández. 2016. "Nutrition, information and household behavior: Experimental evidence from Malawi." Journal of Development Economics. 122:113-126.

Jimoh, A., Sofola, O., Petu, A., & Okorosobo, T. (2007). Quantifying the economic burden of malaria in Nigeria using the willingness to pay approach. Cost Effectiveness and Resource Allocation, 5, 6. http://doi.org/10.1186/1478-7547-5-6.

Kremer, Michael and Edward Miguel. 2007. "The Illusion of Sustainability." The Quarterly Journal of Economics, 122 (3) 1007–1065.

Livinus C, Ibrahim MO, Isezuo S, Bello SO. 2009. The impact of training on malaria treatment practices: a study of patent medicine vendors in Birnin-kebbi. Sahel Medical Journal 12 (2): 58-64.

Gertler, Paul, Luis Locay, and Warren Sanderson. 1987. "Are user fees regressive? The welfare implications of health care financing proposals in Peru." Journal of Econometrics 36 (1–2): 67–88.

Goodman, Catherine, William Brieger, Alasdair Unwin, Anne Mills, Sylvia Meek, and George Greer. 2007. Medicine Sellers and Malaria Treatment in Sub-Saharan Africa: What Do They Do And How Can Their Practice Be Improved? Am J Trop Med Hyg. 77(6 Suppl):203-18.

Mansuri, Ghazala and Vijayendra Rao. 2013. Localizing Development: Does Participation Work?. Policy Research Report. Washington, DC: World Bank.

Meredith, Jennifer, Jonathan Robinson, Sarah Walker, Bruce Wydick. 2013. Keeping the Doctor Away: Experimental Evidence on Investment in Preventative Health Products, Journal of Development Economics.

Ogunfowokan, O. and Mora, M. 2012. Time expectation and satisfaction: Patient experience at National Hospital Abuja, Nigeria. Afri, Prim, Health Care Fam. Med. 4(1), Art. 398, 106-109

Okeke TA & Uzochukwu BS. 2009. Improving childhood malaria treatment and referral practices by training patent medicine vendors in rural south-east Nigeria. Malaria Journal 20, 8.

Oladepo O, Salami KK, Adeoye BW, Oshiname F, Ofi B, et al.. 2007. Malaria treatment and policy in three regions in Nigeria: the role of patent medicine vendors. Working Paper. Future Health Systems.

Onwujekwe, O., Uguru, N., Etiaba, E., Chikezie, I., Uzochukwu, B., & Adjagba, A. 2013. The Economic Burden of Malaria on Households and the Health System in Enugu State Southeast Nigeria. PLoS ONE, 8(11).

Joseph P. Romano, Michael Wolf. 2005. “Stepwise Multiple Testing as Formalized Data Snooping.” Econometrica, 73:4. 1237-1282.

Sachs, Jeffrey, and Pia Malaney. 2002. “The economic and social burden of malaria.” Nature 415.6872: 680-685.

World Bank. 2003. World Development Report 2004: Making Services Work for Poor People. New York, NY: Oxford University Press.

World Health Organization. 2017. World Malaria Report.

Appendix

1. Brief Literature Review on Two Approaches

Despite high volumes of funding to control malaria, there has been limited achievement in Nigeria as well as in other developing countries mainly due to various health constraints in both the demand and supply-side. On the demand side, poor households face high user fees and transportation costs which limit their access to seeking health care (Gertler, Locay and Sanderson, 1987). They are also reluctant to seek care from formal health facilities due to perceived irregularity of services and long waiting times (Ogunfowokan and Mora, 2012). Lastly, households in the developing countries invest little in preventive health measures largely due to financial constraints as well as lack of information (Dupas, 2011b).

Nevertheless, increasing demand for health may not be a solution. Recent findings suggest that poor people lack access to quality of health care even when they seek care from formal health facilities. Das and Hammer (2014) show that percentage of children under five who seek care for their illness in developing countries do not differ substantially from the percentage in the United States. Instead, the quality of medical advice they receive are inadequate. For instance, in Delhi, a doctor spends on average only 3.5 minutes with a patient and performs less than one examination procedure (Das et al. 2008). Dunsch et al. (2017) also describe the low quality of public health facilities in Nigeria and the limited achievement in their attempt to improve their quality mainly due to lack of incentives by public health facility workers. Based on the belief that the public health facilities may lack the incentive or ability to effectively deliver services to the poor, development practitioners increasingly try to involve the private sector as well as community participation in order to improve health service delivery. At the same time, there is lack of rigorous studies of these approaches in controlling malaria.

Private-Sector Approach

In many developing countries, private sector is often the first source of treatment for common illnesses including malaria due to its accessibility. Private medicine sellers are preferred than other sources of treatment since they are generally closer to home than formal facilities, have faster services, and open longer hours. The 2015 Nigeria Malaria Indicator Survey shows that 51% of

children under 5 with fever sought care from patent medicine vendors. At the same time, studies show that private medicine sellers have poor knowledge on drugs as well as malaria symptoms (Goodman et al. 2009). Also, there are concerns about the quality of drugs sold by private medicine sellers (Oladepo et al. 2007).

In response to lack of knowledge and poor quality of drugs sold by PMVs, many development programs aim to improve health outcomes by training PMVs. The existing studies in Nigeria on PMV training, however, are very small scale and offer at most suggestive evidence, with contradictory conclusions. Okeke and Uzochukwu (2009) find that PMVs can be trained to provide quality malaria control services, which supports their inclusion in malaria control strategies. At the same time, Livinus et al. (2009) find that training of PMVs improves knowledge, but there is no improvement observed in practice. In the only experimental evaluation on training local private sector healthcare providers, Cohen et al. (2015) find that training private drug shops in Uganda in RDT use leads to increase in rate of testing, but no increase in ACT use for confirmed cases.

Community Approach

Based on the belief that the public sector may lack the incentive or ability to effectively deliver services to the poor, development practitioners increasingly try to involve community participation since the community members may have the incentive to improve the quality of public goods and services and the necessary information to monitor the providers. At the same time, randomized evaluations have found mixed evidence on the positive impact of involving community workers in health projects. Most recently, Bjorkman, Leight and Sharma (2019) find that the community health workers increased the number of antenatal and postnatal visits among pregnant women in Nigeria, but did not increase the probability of a facility-based delivery, and did not have any significant impact on neonatal health outcomes including birth weight.

Appendix Table

Appendix Table 1: Malaria-related Knowledge by Treatment Arms

	(1)	(2)	(3)	(4)	(5)
	Regression Coefficients and Standard Errors				
	Control mean	CDD	PMV	CDD+PMV	N
Knowledge Index	**0.00 {1.00}**	**0.17** (0.070)**	**0.26*** (0.065)**	**0.26*** (0.064)**	**4265**
Percentage reporting main cause of malaria as mosquito	0.926 {0.263}	0.004 (0.014)	0.015 (0.013)	0.011 (0.013)	4265
Percentage reporting danger sign of malaria as fever	0.788 {0.409}	0.034 (0.023)	0.077*** (0.021)	0.058*** (0.021)	4265
Percentage reporting vulnerable group as children under 5 or pregnant women	0.635 {0.482}	0.016 (0.029)	0.022 (0.029)	0.034 (0.030)	4265
Percentage reporting best protection against malaria as mosquito net	0.865 {0.341}	0.033 (0.021)	0.037* (0.019)	0.038* (0.020)	4265
Percentage reporting best treatment for malaria as ACT	0.26 {0.439}	0.036 (0.030)	0.095*** (0.030)	0.10*** (0.030)	4265
Percentage knowing RDT	0.21 {0.407}	0.087*** (0.032)	0.076** (0.030)	0.083*** (0.029)	4265

Note: Includes village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.

Appendix Table 2: Malaria Prevention Behavior by Treatment Arm

	(1)	(2)	(3)	(4)	(5)
	Regression Coefficients and Standard Errors				
	Control mean	CDD	PMV	CDD+PMV	N
Behavior Index	0.000 {1.00}	0.004 (0.086)	0.020 (0.085)	0.045 (0.076)	4265
Percentage of households sprayed dwelling	0.108 {0.31}	-0.002 (0.029)	-0.014 (0.027)	0.008 (0.027)	4265
Mosquito net ownership (observed mosquito net at the time of interview)	0.594 {0.491}	0.011 (0.038)	0.009 (0.039)	-0.015 (0.036)	4265
Percentage of household members sleeping under a net is higher than 50	0.543 {0.498}	-0.038 (0.030)	-0.005 (0.032)	0.014 (0.029)	4265
Percentage reporting protection used against malaria as mosquito net	0.776 {0.417}	0.026 (0.025)	0.046* (0.025)	0.047* (0.024)	4265

Note: Includes village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.

Appendix Table 3: Care-seeking Behavior by Treatment Arm

	(1)	(2)	(3)	(4)	(5)
	Regression Coefficients and Standard Errors				
	Control mean	CDD	PMV	CDD+PMV	N
Consult health professional					
Children under five	0.75	0.057	-0.016	-0.034	410
	(0.043)	(0.071)	(0.069)	(0.072)	
Children 5-12	0.67	-0.011	-0.018	0.061	368
	(0.043)	(0.071)	(0.082)	(0.082)	
Diagnosed with RDT or microscopy					
Children under five	0.27	-0.15***	-0.083	-0.091	410
	(0.044)	(0.054)	(0.057)	(0.064)	
Children 5-12	0.13	0.023	-0.0053	0.11*	368
	(0.028)	(0.052)	(0.051)	(0.063)	
ACT treated					
Children under five	0.26	0.026	0.082	0.100	410
	(0.046)	(0.071)	(0.081)	(0.079)	
Children 5-12	0.23	0.065	0.17**	0.15*	368
	(0.044)	(0.081)	(0.071)	(0.076)	

Note: The sample includes individuals who experienced fever/malaria in the past 4 weeks. All regressions include village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.

Appendix Table 4: Baseline PHF Characteristics

	Below-median PHF		**Above-median PHF**		**Total**	
	mean	**n**	**mean**	**n**	**mean**	**n**
Infrastructure						
24-hour emergency service available at this facility	0.48	137	0.8	138	0.64	275
Reception or registration room	0.63	140	0.87	140	0.75	280
Indoor waiting area for patients	0.51	140	0.78	140	0.65	280
Separate waiting room for women in the facility	0.25	140	0.54	140	0.39	280
Air-conditioning in patient areas	0.09	140	0.11	140	0.1	280
Observation beds	0.71	140	0.86	140	0.79	280
Accommodations for persons on-call present	0.21	140	0.57	140	0.39	280
Water is available for all working hours	0.76	140	0.71	140	0.73	280
Refer patients to other facilities	0.48	140	0.49	140	0.49	280
Access to transportation for patients	0.09	140	0.11	140	0.1	280
Access to a functioning computer	0.01	140	0.01	140	0.01	280
Separate drug storage area	0.35	136	0.72	139	0.53	275
Laboratory in this health facility	0.01	135	0.15	134	0.08	269

Have access to electricity	0.5	135	0.63	136	0.56	271
Have access to clean water	0.69	133	0.7	135	0.7	268
Have telephone	0.59	140	0.49	140	0.54	280
Administration and Management						
Meetings held more than 4 times in the past year	0.38	140	0.59	140	0.48	280
Facility has workplan developed for this year	0.31	136	0.6	140	0.46	276
Has written emergency preparedness plan	0.12	137	0.22	140	0.17	277
Community group supervises the work	0.72	140	0.9	140	0.81	280
Community supervision visits in the last 6 months	0.39	140	0.59	140	0.49	280
Have written recommendations from community visit	0.06	140	0.3	140	0.18	280
Community group makes formal recommendations	0.48	137	0.66	138	0.57	275
Have written recommendations from the meeting	0.01	137	0.2	138	0.11	275
Have written recommendations from LGA visit	0.14	140	0.52	140	0.33	280
If NGO made supervision visits in the past 6 months	0.16	140	0.33	140	0.25	280
Supervisory visits to community health workers	0.37	140	0.63	140	0.5	280
Staff performance was internally assessed	0.42	140	0.59	140	0.5	280
Staff performance was externally assessed	0.44	140	0.66	140	0.55	280
Obtained patient opinion through client survey	0.67	135	0.79	140	0.73	275
Changes occurred as a result of patient opinion	0.53	135	0.68	140	0.61	275
Have a written document of annual budget	0.04	139	0.09	139	0.06	278
PHF worker's satisfaction score (Scale -2 to 2)						
Working relationship with LGA health authorities	0.74	131	1.09	139	0.92	270
Working relationship with state health authorities	0.78	125	1.16	132	0.98	257
Management of health facility	0.84	137	1.27	139	1.06	276
Relationships with local traditional leaders	0.49	134	1.17	134	0.83	268
Availability of medicine in the health facility	-0.85	138	0.33	138	-0.26	276
Availability of equipment in the health facility	-0.99	138	0.27	138	-0.36	276
Physical condition of the health facility building	-0.65	138	0.5	137	-0.08	275
Your ability to provide high quality care	0.86	136	1.17	138	1.01	274
Your respect in the community	1.04	136	1.3	138	1.17	274
Your training opportunities to upgrade your skill	-0.18	135	0.44	137	0.13	272
Your salary	-1.15	136	-0.18	138	-0.66	274
Employment benefits	-1.15	135	-0.39	137	-0.77	272
Security to practice in the community	-0.1	134	0.56	138	0.23	272
Living accommodations for your family	-0.23	132	0.54	138	0.16	270
Your boss' recognition of your good work	0.93	136	1.34	138	1.14	274
Your opportunities for promotion	0.01	135	1.01	137	0.51	272
Overall satisfaction	0.98	136	1.47	136	1.22	272
Community relationship/outreach activities						
At least 40% of village population attended facility	0.06	126	0.07	135	0.07	261
CDDs provide health care services	0.54	140	0.64	140	0.59	280
This facility has a designated supervisor for CDDs	0.37	118	0.43	122	0.4	240
Held training/meetings for community health workers	0.51	140	0.67	140	0.59	280
Held training/meetings for CDDs	0.51	140	0.64	140	0.58	280

Communities in general support this facility	2.98	140	4.14	140	3.56	280
Are user fees being collected for outpatient visits?	0.61	137	0.75	140	0.68	277
Patients pay for registration or consultation fees	0.56	136	0.73	139	0.64	275
Patients pay fees for medicine	0.44	133	0.6	137	0.52	270
Malaria diagnosis and treatment is present	0.82	136	0.94	139	0.88	275
Malaria-related knowledge of health workers						
Knowledge on cause of malaria	0.98	138	0.99	139	0.98	277
Knowledge on danger sign of malaria	0.94	140	0.94	140	0.94	280
Knowledge on mosquito net	0.98	140	0.99	140	0.98	280
Knowledge on ACT	0.95	140	0.96	140	0.95	280

Appendix Table 5: Baseline Community Characteristics

		(1)		(2)	T-test
		Below median PHF		Above median PHF	Difference
Baseline Community Characteristics	N	Mean/SE	N	Mean/SE	(1)-(2)
Number of households	133	7844.188	138	7557.312	286.876
		[1473.053]		[1223.895]	
Paved road	137	0.175	140	0.221	-0.046
		[0.033]		[0.035]	
Vehicles pass on the main road	130	0.854	136	0.912	-0.058
		[0.031]		[0.024]	
Existence of water body	131	0.618	133	0.617	0.002
		[0.043]		[0.042]	
Main religion as Catholic	137	0.891	140	0.943	-0.052
		[0.027]		[0.020]	
Main ethnicity as Igbo	137	0.956	140	0.971	-0.015
		[0.018]		[0.014]	
Market within community	133	0.820	125	0.832	-0.012
		[0.033]		[0.034]	
Access to clean water source	137	0.540	140	0.636	-0.096
		[0.043]		[0.041]	
Households own private toilet	137	0.818	140	0.907	-0.090**
		[0.033]		[0.025]	
Households grow crops	130	0.838	134	0.918	-0.079**
		[0.032]		[0.024]	

Appendix Table 6: Impact on Malaria by Community Characteristics

	(1)	(2)	(3)	(4)	(5)
VARIABLES	RDT under 5	RDT 5-12	Knowledge	Diagnosis	ACT treated
CDI treatment	-0.039*	-0.050	0.253**	-0.018	0.078*
	(0.021)	(0.037)	(0.103)	(0.036)	(0.044)
PMV treatment	-0.043*	-0.015	0.384***	0.025	0.117***
	(0.025)	(0.039)	(0.097)	(0.031)	(0.038)

CDI+PMV treatment	-0.044*	-0.081**	0.435***	0.020	0.102**
	(0.024)	(0.037)	(0.086)	(0.035)	(0.046)
CDI*community	0.090**	-0.002	-0.098	-0.101*	-0.098
	(0.042)	(0.066)	(0.170)	(0.059)	(0.077)
PMV*community	0.000	-0.090	-0.142	-0.103	-0.093
	(0.033)	(0.057)	(0.168)	(0.065)	(0.096)
(CDI+PMV)*community	0.083*	0.028	-0.265	-0.059	-0.122
	(0.044)	(0.059)	(0.168)	(0.067)	(0.081)
Above median community	-0.041*	0.026	0.111	0.059	0.078
	(0.022)	(0.043)	(0.126)	(0.041)	(0.054)
Constant	0.101	0.066	2.484***	-0.128	-0.445
	(0.110)	(0.189)	(0.481)	(0.188)	(0.275)
Observations	1,932	1,550	4,188	1,971	1,971
R-squared	0.019	0.028	0.026	0.016	0.025

Note: Includes village-level baseline household control variables, village-level baseline value of dependent variable and senatorial district dummies.

Appendix Table 7: PMV knowledge on ACT by quality of PHF

	(1)	(2)
	Below-median PHF	Above-median PHF
	PMV knowledge on ACT	
CDD	-0.088	0.057
	(0.054)	(0.060)
PMV	0.009	0.110**
	(0.030)	(0.048)
CDD+PMV	0.019	0.086*
	(0.029)	(0.052)
Constant	0.955***	0.841***
	(0.025)	(0.043)
Observations	351	361

Note: Based on PMV survey conducted at endline.