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The Impact of Subsidized Antimalarials on Treatment Seeking Behavior

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Abstract

I investigate the effect of the first multi-country antimalarial subsidy on the type and source of treatment taken for children under five years of age reporting a fever. I use nationally representative, cross-sectional survey data from 15 malaria endemic African countries over an 11 year period. My research design exploits the within country variation in malaria treatment subsidies. Artemisinin-based Combination Therapies (ACTs) are the recommended first line treatment for uncomplicated malaria. Overall, the ACTs subsidy achieved two of its main objectives. Among children reporting a fever, countries offering subsidized ACTs increased ACTs taken in the private sector by 6.8 percent and decreased treatment with lesser effective antimalarial monotherapies by 9.0 percent. However, the effect of the ACTs subsidy was not consistent among the three participating countries studied. Uganda showed the intended response with the greatest magnitude to the subsidy, whereas no significant effect was observed in Ghana or Nigeria. The mixed results among countries participating in the ACTs subsidy may be due to differences in ACTs availability, price, market share, and supporting interventions.

Keywords: Malaria, subsidy, Artemisinin-based combination therapies (ACTs), Affordable Medicines Facility-malaria, Private Sector Co-payment Mechanism
JEL codes: I11, I12, I18

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1 Introduction

In sub-Saharan Africa, an estimated 292,000 deaths due to malaria among children under five years of age occurred in 2015 (WHO, 2015*b*). Children under five years of age account for 78 percent of all deaths due to malaria. Many of these deaths could be prevented if children received Artemisinin-based combination therapies (ACTs) to treat malaria.

Prior to 2011, the majority of children obtained ACTs from public sector outlets such as public hospitals, health centers, and health posts. Although ACTs are typically provided for free in the public sector, there are many challenges to obtaining treatment in this setting such as overcrowding of health facilities resulting in long waits to be treated during limited operating hours (Brugha and Zwi, 1998; Cohen, Dupas and Schaner, 2015). In addition, people often have to travel long distances to reach public sector outlets (Foster, 1995; Lindelow, 2005). Stock-outs of ACTs (Barrington, Wereko-Brobby and Ziegler, 2010; Kangwana et al., 2009; World Bank, 2010) and the provision of ineffective monotherapy drugs (Talisuna et al., 2009) have also been reported. These factors lead to a negative perception of the providers and health facilities quality resulting in the decision to seek treatment in the private sector (Leonard, Mliga and Mariam, 2002; Leonard, 2007).

To address these challenges, the Global Fund initiated two financing models to offer subsidized ACTs in private sector outlets, the Affordable Medicines Facility-malaria (AMFm) and the Private Sector Co-Payment Mechanism. The four main objectives shared by the financing models are to: increase ACTs affordability, increase ACTs availability, increase ACTs use, and crowd out monotherapies by increasing the market share for ACTs (AMFm IET, 2012). The subsidy allowed for ACTs to be purchased in private sector outlets in an over-the-counter format at a subsidized price with a range of US $0.60 to $1.96 per adult equivalent treatment. Critics of subsidized ACTs were concerned with the sustainability of the financing models; ACTs reaching the target population and the sale of ACTs to people without malaria (Maxmen, 2012). Proponents of subsidized ACTs found them to be effective in rapidly improving availability, price, and market share of ACTs (Tougher et al., 2012). Ev-

idence from the long term impact of subsidized ACTs on the reduction of lesser effective antimalarial monotherapies and the source of ACTs used to treat malaria is needed.

In this paper I assess if subsidized ACTs offered in private sector outlets increase ACTs taken in the private sector and decrease treatment with lesser effective antimalarial monotherapies. I use data on 110,676 children under five years of age reporting a fever in nationally representative, cross-sectional surveys from 15 sub-Saharan African countries over the period 2006-2016. In high transmission areas, children under five years of age are the most vulnerable group affected by malaria (WHO, 2016). Three of the 15 countries included in the analysis, Ghana, Nigeria, and Uganda, participated in the ACTs subsidy. I employ a difference-in-differences study design, which allows for a causal identification of the effect of subsidized ACTs on treatment seeking behavior in Africa[1].

I fill three gaps that exist in the previous literature on the impact of ACTs on treatment seeking behavior. First, my research includes treatment with ACTs from *all public and private sector outlets before and after the ACTs subsidy*. Littrell et al. (2011) conducted cross-sectional surveys in six African countries in 2009 to establish a pre-ACTs subsidy measure of treatment seeking behavior in public and private sector outlets. Their study found that ACTs availability was lowest in private sector outlets prior to the start of the ACTs subsidy. They also reported that in the private sector, ACTs were typically six to 21 times as expensive as the most commonly sold/distributed antimalarial (lesser effective antimalarial monotherapies). The authors' study design analyzed each country separately (i.e., no comparison group) and did not extend the study to the post-ACTs subsidy period.

Other studies focused on ACTs only in private sector outlets (i.e., the following studies did not include ACTs from public sector outlets). For an ACTs subsidy pilot study, Sabot et al. (2009*a*) conducted a randomized controlled trial in three rural districts of Tanzania

[1]Identifying the appropriate control group for the participating countries is a challenge. One possible solution is the synthetic control method (SCM) by Abadie, Diamond and Hainmueller (2010). Unfortunately, the SCM could not be implemented due to data limitations; the SCM requires a balanced panel for the outcome variables. The surveys used for the analysis were not administered in consecutive years or the same intermittent years for each country.

during August 2007 through August 2008. The authors found that the proportion of people in participating districts who purchased subsidized ACTs from private sector shops rose from 1 percent at baseline to 44.2 percent one year later. Cohen et al. (2010) conducted cross-sectional surveys on private retailers located in rural Tanzania in 2010. The authors reported treatment with ACTs increased from negligible levels to nearly half of total antimalarial sales over the course of the study. Cohen, Dupas and Schaner (2015) used a randomized controlled trial in three districts of rural Kenya between May and December of 2009 to study price setting for the ACTs subsidy and found that at the highest ACTs subsidy level, the share of illnesses treated with ACTs increased from 19 to 41 percent.

Second, I assess a *long-term post-subsidy period* by including data on six years after the ACTs subsidy launch date. The long-term post-subsidy period is necessary to show the sustainability of the ACTs subsidy during the time period when participating countries must allocate their own resources to maintain the policy change (i.e., year 2012 and later). My analysis of changes in treatment seeking behavior over time shows that the fraction of children taking ACTs from the private sector increased by 2 to 6 percent per year starting in the third year after the ACTs subsidy was introduced.

Previous research only considered a short-term effect, which is problematic if countries participating in the ACTs subsidy are not able to maintain the subsidy over time or if some facets of the policy change take additional time to implement. Challenges to implementing the financing models that warrant a longer post-subsidy period include ensuring subsidized ACTs are available in the private sector outlets (AMFm IET, 2012), setting the price of ACTs in private sector outlets to be lower than the price of lesser effective antimalarial monotherapies (AMFm IET, 2012), training retailers on how to prescribe the correct dosage (Sabot et al., 2009*b*), ACTs stock-outs in rural settings (Davis et al., 2013), and generating awareness of the ACTs subsidy through mass communication campaigns (Willey et al., 2014).

Third, my study assesses changes in treatment seeking behavior *under routine conditions for three participating countries* (i.e., Ghana, Nigeria, and Uganda) not included in the prior

research that utilized experimental studies. I use nationally-representative, cross-sectional survey data containing detailed information on the child, household characteristics, and factors affecting malaria transmission. This leads to improved external validity compared to the studies on subsidized ACTs that used randomized controlled trials in a few districts for a short duration in a single participating country (i.e., Kenya or Tanzania). Although randomized controlled trials are the gold standard for causal research, they sometimes lack external validity in this context because knowledge of ACTs, cultural customs with respect to treatment decisions, and ACTs availability may be location-specific. In addition, participants in randomized controlled trials may also suffer from the Hawthorne Effect; participants adjust their behavior because they are aware they are being studied. My results show that there were heterogeneous treatment effects among the three participating countries studied.

The main results of my research are that national-level participation in the ACTs subsidy is associated with a statistically significant 6.8 percent increase in children with fever taking ACTs in the private sector. This is complemented by a marginally significant 9.0 percent decrease in children with fever taking lesser effective antimalarial monotherapies from any sector. No significant effect was found for ACTs taken in the public sector. Therefore, the funding mechanisms were successful at increasing the use of ACTs in the private sector, but need to take further action to crowd out monotherapies. After a country government has confirmed progress with increasing ACTs affordability, availability, and use, they should take efforts to decrease the future procurement of lesser effective monotherapies. When assessing these changes over time, take-up is slowly increasing, but appears to be sustainable.

After assessing the overall impact of the ACTs subsidy, I investigate the effect of the ACTs subsidy on each participating country separately. Among the countries participating in the subsidy, Uganda is driving the change in the overall results. In Uganda, I observed a statistically significant increase in taking ACTs in the private sector and a decrease in taking non-ACTs in any sector of 19.1 and 18.7 percent, respectively. These findings are supported by the price of ACTs to the patient. When comparing the difference in the price

of ACTs in the private and public sector, Uganda had the largest difference in price during the post-subsidy period.

2 Background

2.1 Malaria

Plasmodium falciparum is the most virulent species of the parasite that causes malaria in humans. It is endemic to sub-Saharan Africa. The symptoms of malaria include fever, chills, perspiration, anorexia, vomiting, and worsening malaise. A malaria diagnosis classified as uncomplicated malaria is defined as a person who presents with symptoms of malaria and a positive parasitological test, but with no features of severe malaria (WHO, 2015*a*). The features of severe malaria include impaired consciousness, prostration, multiple convulsions, acidosis, hypoglycemia, severe malaria anemia, renal impairment, jaundice, pulmonary edema, significant bleeding, shock, and hyperparasitemia. The severity of malaria infection is highly dependent on a person's prior acquired protective immunity. The degree of immunity to malaria is a result of the malaria transmission intensity level of the person's place of residence.

2.2 Artemisinin-based Combination Therapies (ACTs)

ACTs have been recommended as the first-line treatment for uncomplicated malaria since 2001 because of their high efficacy and their ability to limit the development of further drug resistance (Sinclair et al., 2009). Prior to 2009, ACTs accounted for only one in five antimalarial treatments taken and were provided almost entirely by the public sector (The Global Fund, 2013*a*). Public sector outlets include government sponsored hospitals, health centers, health posts, mobile clinics, and community health workers. In most cases, the public sector outlets provide free health care and treatment to all patients, regardless of socioeconomic status.

Also prior to 2009, more than 60 percent of patients accessed some form of antimalarial treatment through the private sector. However, ACTs were not widely used in the private sector because they were more expensive (between US $4 - $13 per treatment) than antimalarial monotherapies. Private sector outlets include for-profit and non-profit hospitals/clinics, pharmacies, doctors, mobile clinics, community health workers, local shops, and traditional practitioners.

2.3 ACTs Subsidy

In response to these challenges, the Affordable Medicines Facility-malaria was a US $500 million test of concept financing model hosted and managed by the Global Fund to expand access to effective and affordable ACTs (AMFm IET, 2012). The financing model took place in Cambodia, Ghana, Kenya, Madagascar, Niger, Nigeria, Tanzania, Zanzibar, and Uganda during 2011 - 2012. It was implemented on a national scale; it is not possible to list states or districts that participated in the subsidy program due to the nature of private sector supply chains that the intervention operated through. The financing model was restructured and renamed the Private Sector Co-Payment Mechanism in 2012. Six African countries: Ghana, Kenya, Madagascar, Nigeria, Tanzania, and Uganda are participating in the Private Sector Co-Payment Mechanism.

Both financing models provide a mechanism for highly subsidized ACTs to be purchased in private sector outlets without a positive malaria diagnostic test. Differences between the two models include the following. The Affordable Medicines Facility-malaria was funded by an independent co-payment source with contributions from external donors; the subsidy level was set by the Global Fund and applied across all countries simultaneously; subsidized ACTs were available in the public and private sector; and subsidized diagnostic testing was not included (The Global Fund, 2013*b*, 2015). The Private Sector Co-Payment Mechanism requires countries to allocate resources from their core Global Fund grant facility; the subsidy level is set by each country and may evolve over time; subsidized ACTs are available only in

the private sector; and subsidized diagnostic tests are being considered.

2.4 Price of ACTs to the Consumer

Appendix Figures A1 - A3 show that there was variation by country in the cost of ACTs to the consumer before and after the ACTs subsidy was implemented.

There were four countries participating in the ACTs subsidy with data available before and after policy change: Ghana, Madagascar, Nigeria, and Uganda. Most notably, Madagascar had an alternative financing mechanism[2] in the pre-subsidy period that offered ACTs at low cost to the consumer in the private sector. This caused there to be an *increase* in the difference in the price of ACTs when comparing private to public sector prices in Madagascar (Appendix Figure A1). Focusing on the source of treatment, there was an *increase* from US \$0.14 to \$0.60 per adult equivalent dose for ACTs in private sector shops and other private outlets in Madagascar after the ACTs subsidy (Appendix Figure A2). As the alternative financing mechanism has the potential to change people's treatment seeking behavior during the pre-ACTs subsidy period, I exclude Madagascar from all analyses.

Focusing on the three treatment countries included in the analysis, there was widespread free provision of ACTs in the public sector before and after the policy change in Nigeria and Uganda (Appendix Figure A2). Only in Ghana was there a fee for ACTs in the public sector. Appendix Figure A1 illustrates that in Ghana, the difference in the price of ACTs in the private sector less the public sector decreases after the subsidy was implemented; however the post-subsidy difference is negligible. The country with the largest change in price of ACTs to the consumers was Nigeria.

[2]Pre-subsidy low ACTs prices were due to the pediatric ACTs subsidy program for Actipal (artesunate-amodiaquine) that Population Services International had been operating in Madagascar since 2008 with distribution through community health workers and private shops.

3 Theoretical Framework

My paper focuses on children under five years of age, the most vulnerable population for malaria illness. When a child has a fever, the mother/caretaker observes the child's symptoms and assesses the subjective probability that the illness is malaria. Although fever is the most common symptom of uncomplicated malaria, having a fever could be due to a variety of different illnesses (i.e., fever due to an acute respiratory infection, for which the symptoms should not be treated with antimalarial drugs)[3]. During this initial assessment, the mother/caretaker's evaluation is done without a confirmatory diagnostic test or guidance from a service provider. However, since children under five years of age have had limited time to develop acquired immunity, the mother/caretaker's assessment has the potential to be accurate. The child's acquired immunity develops faster in areas with stable, high malaria transmission intensity.

If the mother/caretaker determines the fever is likely to be caused by malaria, she next makes the decision to seek treatment for the child. If she takes no action, then she will allow the child's illness to resolve on its own. If she decides to seek treatment for the child, then she has a variety of options. In the private sector, she may choose from a hospital/clinic, pharmacy, private doctor, mobile clinic, community health worker, shop, traditional practitioner, or other private outlet. In the public sector, she may choose from a government hospital, health center, mobile clinic, community health worker, health post, or other public outlet.

There are a number of constraints that impact a mother/caretaker's decision to seeking treatment for malaria. As discussed earlier in this paper, there are challenges to accessing a service provider and/or treatment for malaria in the private and public sectors. In the public sector, treatment is typically provided for free. However, there may be long wait times, the mother/caretaker may have to travel long distances to reach the outlet, drug stock-outs occur,

[3]I restrict the analysis on drugs taken to treat malaria to ACTs and non-ACTs (i.e., lesser effective antimalarial monotherapies) to avoid cases where treatment with a non-antimalarial is the appropriate course of action.

and lesser effective drugs may be prescribed. In the private setting, the mother/caretaker will still have to visit a service provider to obtain a prescription for treatment and the cost of the visit and malaria treatment may be outside the mother/caretaker's budget constraint.

Another factor affecting the mother/caretaker's source for treatment is the opportunity to seek clinical evaluation from a service provider. If the child is taken to a hospital (private or public), health center (private or public), or pharmacy, then the mother/caretaker will have the opportunity to consult with a service provider and receive guidance on the appropriate treatment for the child. In some cases, a diagnostic test will be used by the service provider to confirm the child has malaria prior to determining the appropriate treatment.

Last, in private sector shops, public health posts, and "other" private and public outlets, it is unlikely that a malaria diagnostic test will be used; the mother/caretaker will have to make her own decision if the child has malaria and what the appropriate drug is to treat malaria. ACTs are the recommended first line treatment for uncomplicated malaria; however, there are many lesser effective drugs available in private and public sector outlets, sometimes offered at prices less than ACTs. In these settings, the mother/caretaker may have limited knowledge on the which drugs to take, appropriate dosage levels for the child, and how to detect quality-assured drugs.

The ACTs subsidy studied in this paper has the potential to make the greatest impact on ACTs taken from private sector pharmacies and shops. The ACTs subsidy financing models aim to make ACTs available and affordable in private sector outlets. For the first time, ACTs are available in an over the counter format and should be set at prices competitive with lesser effective monotherapies. However, making ACTs accessible without consultation from a service provider means that diagnosis of malaria and treatment selection is done by the mother/caretaker, often with no diagnostic testing and limited guidance from retailers.

In conclusion, relating the theoretical framework to the outcomes assessed in this paper, ACTs taken from the private sector should experience an increase after the subsidy and non-ACTs taken from any sector should see a decrease after the subsidy. Substitution effects from

other private and public sector outlets may be observed if the mother/caretaker changes her source for uncomplicated malaria treatment from the public to the private sector.

4 Data and Summary Statistics

The data come from three primary sources: Demographic and Health Surveys (DHS) (NSO and ICF, 2006-2016*a*), Malaria Indicator Surveys (MIS) (NSO and ICF, 2006-2016*b*), and Multiple Indicator Cluster Surveys (MICS) (UNICEF, 2006-2016) from 15 sub-Saharan African countries during years 2006-2016. These are nationally representative, cross-sectional surveys that use the same modules to collect individual demographic data as well as a malaria module on the type, sector, and source of treatment for children with fever. Appendix Table B1 summarizes the 71 country-years of data among the 15 countries studied. Appendix Table B2 lists the data source and number of children with fever by country-year.

The data universe is restricted to children aged 0-59 months who reported having a fever during the two weeks prior to the household interview. Having a fever is used as a proxy for having malaria since most households would not have access to a diagnostic test to confirm if the child has malaria. A total of 110,676 children were included. The individual-level data were collapsed down to country-level averages before running regressions.

Survey data from years prior to 2006 are excluded because less effective antimalarial drugs than ACTs that are prone to malaria resistance were available and frequently prescribed to treat malaria during the period before year 2006. The following country-months are excluded because there was a gap between the date that subsidized ACTs were available in the private sector and the date of the official study launch (AMFm IET, 2012): Ghana: August 2010 January 2011, Nigeria: January 2011 February 2011, and Uganda: no exclusions. In addition, four MICS surveys representing country-years Ghana 2010, Malawi 2006, Nigeria 2011, and Sierra Leone 2010 collected data on the type of treatment taken for fever (i.e., ACTs or non-ACTs), but did not collect data on the treatment source (i.e., public or

private sector). Data from these four country-years are excluded from all analyses.

I do not restrict the dataset to include only regions with medium or high malaria transmission for two reasons. First, the intervention was implemented nationwide; it was not restricted to areas with higher malaria transmission. Second, all children included in the dataset reported having a fever during the last two weeks (i.e., fever is a proxy for malaria). Therefore, I want to assess their treatment seeking behavior for malaria regardless of which region they live in.

4.1 Treatment Assignment

Figure 1 is a map of the countries included in the analysis. Three countries, Ghana, Nigeria, and Uganda, participate in the national-level ACTs subsidy under the Affordable Medicine Facility-malaria and Private Sector Co-Payment Mechanism financing models[4]. Twelve sub-Saharan African countries with endemic malaria that have data available pre- and post- the ACTs subsidy are included as control countries[5]. The control countries are Angola, Benin, Cameroon, Cote d'Ivoire, Liberia, Malawi, Mali, Mozambique, Rwanda, Senegal, Sierra Leone, and Zambia. The 15 countries included in the analysis represent all sub-Saharan African countries with nationally representative survey data collected before and after the introduction of subsidized ACTs. I focus on sub-Saharan African countries since these countries have the highest rates of *Plasmodium falciparum* malaria.

[4]There were six additional countries that participated in at least one of the two ACTs subsidy financing models that were excluded from the analysis: Cambodia, Kenya, Madagascar, Niger, Tanzania, and Zanzibar. Cambodia was excluded because it is not located in Sub-Saharan Africa. Kenya, Niger, and Tanzania had data pre- and post- the subsidy period, but did not have any data collected during the years of participation in the financing models. Kenya and Tanzania also had ACTs subsidy pilot studies implemented during the pre-intervention years. Data for Madagascar are excluded from all analyses because Madagascar had an alternative financing mechanism, the pediatric ACTs subsidy program for Actipal (artesunate-amodiaquine) that Population Services International had been operating in Madagascar since 2008 with distribution through community health workers and private shops. Zanzibar did not have data available.

[5]Namibia, Swaziland, and Zimbabwe had data available, but were excluded from the analysis as malaria transmission in these countries is very low and not very comparable to the participating countries. The Gambia had survey data available, but was excluded from the analysis because there were no GPS coordinates available.

4.2 Outcomes

There are three outcomes studied to evaluate the impact of the ACTs subsidy on treatment seeking behavior. The three outcomes are initially constructed as binary variables using the individual-level dataset. The data are later collapsed down to the country-year level to form the fraction of children with fever seeking treatment by sector. I exclude antibiotics and any other treatments taken for fever that do not meet the definitions of ACTs and non-ACTs. The reason for this exclusion is that fever may be the symptom of many other illnesses where non-antimalarial treatment is appropriate.

"Took ACTs in Private Sector" is a binary variable equal to 1 if the child took ACTs for fever from any of the following private sector sources: hospital/clinic, pharmacy, dispensary, chemist, doctor, mobile clinic, community health worker, shop, traditional practitioner, drug peddler, friend, church, or other private source. ACTs are defined as taking Artemisinin-based combination therapies for fever. This includes country-specific responses for treatment with ACTs: ACTipal, Artemether-Lumefantrine, Amomate/Falcimon/Arsucam, Artimodi, Artesunate and Amodiaquine, ASAQ, Coarsucam, Coartem, combination with Artemisinin, Amomate/Falcimon/Arsucam, and Primo. If any of these country-specific drug names were marked as been taken on the survey then the child was coded as taking an ACT. The outcome variable is equal to 0 otherwise.

"Took ACTs in Public Sector" is a binary variable equal to 1 if the child took ACTs for fever from any of the following public sector sources: hospital, health center, mobile clinic, community health worker, health post, other public source. It is equal to 0 otherwise. ACTs are defined as described above. The variables representing the different sources of treatment are clearly coded as public and private sector on each survey to avoid ambiguity.

"Took Non-ACTs in Any Sector" is a binary variable equal to 1 if the child took non-ACTs from either the private or public sector. It is equal to 0 otherwise. This outcome is not restricted to the public or private sector because the objective of the ACTs subsidy that this outcome represents is to push out antimalarial monotherapies. Non-ACTs are defined

as treatment for malaria with a lesser effective antimalarial monotherapy. This includes country-specific responses for treatment with ACTs: Amodiaquine, Arinate, Arthemether, Chloroquine, Lumefantrine, Mefloquine, Quinine, SP/Fansidar, or other antimalarial. If any of these country-specific drug names were marked as been taken on the survey then the child was coded as having taken an non-ACT.

A fourth outcome is used in one of the falsification tests. "No Fever, Took ACTs in Any Sector" is equal to 1 if the child took ACTs (as defined above) from either the private or public sector, but did not have a fever in the last two weeks.

4.3 Covariates

Covariates from the DHS, MIS, and MICS sources of data are the demographic characteristics of the head of household (age and sex), mother/caretaker (age, sex, and education), and child (age, sex, wealth index, and place of residence). Covariates on malaria prevalence factors, malaria transmission intensity and average monthly precipitation, are two of the factors that may contribute towards the mother/caretaker's decision to seek treatment for a child with fever. Both are dependent on the time of year the survey data were collected and are included in the analysis to control for the differences in the timing of the surveys. To construct these covariates, GPS coordinates of the household were obtained from all DHS and MIS surveys that offer publicly available GPS data. The MICS source does not offer GPS data. The methods used for geo-referencing households with missing GPS coordinates are described in Appendix D. The GPS data were used to construct additional covariates not available in the three main data sources. I used ArcMap v10.3.1 software to match the child's place of residence to the closest coordinates with data on malaria endemicity and average monthly rainfall, which come from The Malaria Atlas Project (2016) and NASA (2016), respectively.

Additional potential covariates were omitted from all analyses because they were not consistently collected across survey-years. The excluded variables include head of household

(education and employment), mother/caretaker (marital status and employment), and child (birth order and vaccination status). Covariates representing participation in other malaria control interventions (e.g., bednet use and indoor residual spraying) were excluded because they represent a mechanism in the causal pathway rather than a confounder. For example, bednet ownership may be related to the subsidy if families receive bednets free of charge at the source they seek treatment for malaria. Similarly, residing in an location covered by govennment programs to spray the home against mosquitoes may be associated with the subsidy if having indoor residual spraying makes people more likely to be aware of the ACTs subsidy and seek treatment with ACTs.

4.4 Summary Statistics

Table 2 shows the pre- and post-ACTs subsidy means for the outcomes and covariates for the participating and control countries. Before the ACTs subsidy, the participating and control countries had approximately equivalent rates of taking ACTs in the private sector. However, the participating countries took fewer ACTs from the public sector and more non-ACTs in any sector compared to the control countries. After the policy change, participating countries experienced a greater increase in children with fever taking ACTs in the private sector compared to that of the control countries. The characteristics of the head of household, mother/caretaker, and child were mostly balanced for participating and control countries before and after the subsidy. Malaria prevalence factors vary for each country due to the time of the survey data collection and location of the household.

5 Methods

I estimate difference-in-differences (DD) models that compare changes in average treatment seeking behavior in countries participating in the ACTs subsidy to changes in average treatment seeking behavior in countries not participating in the ACTs subsidy. The data

consists of all children ages 0-59 months reporting a fever during the past two weeks (from the time of the survey interview) over the period 2006-2016. The individual-level outcome and covariate data were collapsed to the country-year level. There are six years of post-policy implementation data: 2011 - 2016.

Equation (1) estimates the overall impact of subsidized ACTs on treatment seeking behavior for an analysis of the three participating countries pooled together. Equation (2) analyzing the contribution of the participating countries, Ghana, Nigeria, and Uganda separately. Equation (2) is included because I predict that not all countries will have the same response to the ACTs subsidy because there may be country-specific challenges to implementing the financing models. The challenges that are unique to each country are discussed in Section 10.

$$\mathbf{Y}_{ct} = \alpha + \delta ACTsubsidy_c + \rho Post2010_t + \beta ACTsubsidy_c * Post2010_t + \eta \mathbf{X}_{ct} + \lambda_c + \mu_t + \epsilon_{ct} \quad (1)$$

$$\begin{aligned} \mathbf{Y}_{ct} = \; & \alpha + \rho Post2010_t + \beta_1 ACTsubsidyGH_c * Post2010_t + \\ & \beta_2 ACTsubsidyNG_c * Post2010_t + \\ & \beta_3 ACTsubsidyUG_c * Post2010_t + \eta \mathbf{X}_{ct} + \lambda_c + \mu_t + \epsilon_{ct} \end{aligned} \quad (2)$$

where $\mathbf{Y}_{ct}$ is the fraction of children with fever seeking treatment in country c in year t in both equations. $\mathbf{Y}_{ct}$ represents three continuous variables: taking ACTs in the private sector, taking ACTs in the public sector, and taking non-ACTs in any sector.

The coefficient of interest is β. There is one interaction term to capture the effect of the policy change in Equation (1), ACTsubsidy$_c$*Post2010$_t$. ACTsubsidy$_c$ is a binary variable equal to 1 if country c is participating in the ACTs subsidy: Ghana, Nigeria, or Uganda. It is equal to 0 if country c is one of the twelve control countries. Post2010$_t$ is equal to 1 if year t is greater than year 2010 and is equal to 0 otherwise.

Equation (2) modifies the parameter of interest to assesses if the policy change effects treatment seeking behavior differently for each participating country. There are three treat-

ment assignment variables, ACTsubsidyGH$_c$*Post2010$_t$, ACTsubsidyNG$_c$*Post2010$_t$, and ACTsubsidyUG$_c$*Post2010$_t$. Each interaction term is comprised of two binary variables, for example, in Ghana they are ACTsubsidyGH$_c$ and Post2010$_t$. ACTsubsidyGH$_c$ is equal to 1 if country c is Ghana. Post2010$_t$ is equal to 1 if year t is greater than year 2010.

In both equations, I include $\mathbf{X}_{ct}$, a vector of country c and year t covariates. Characteristics of the head of household include a continuous variable for age in years and the fraction female. Characteristics of the mother/caretaker include continuous variables for age in years and years of education. Characteristics of the child include a continuous variable for the age in months, the fraction female, the fraction residing in a rural area, and the fraction for the household's wealth quintile (i.e., poorest, poorer, rich, richer, and richest). Continuous variables for malaria transmission intensity and average monthly precipitation were included to control for changes in malaria prevalence that may independently influence treatment seeking behavior.

To control for unobservable determinants of treatment seeking behavior, I include country and year fixed effects. Country fixed effects (λ_c) control for country-specific, time-invariant effects (average treatment seeking behavior may be different in each country). As can be inferred from the summary statistics in Table 2, country fixed effects are necessary to absorb other determinants of treatment seeking behavior, but leave enough variation for the identification of the effect of interest. Year fixed effects (μ_{ct}) control for year-specific, country-invariant effects (e.g., average treatment seeking behavior across all countries - those participating in the ACTs subsidy and not participating - may be different in years 2006, 2007, etc.). The error term (ϵ_{ct}) reflects the idiosyncratic variation in potential outcomes across countries and time.

To account for within-group dependence (i.e., the outcome variable is highly correlated with country) in estimating standard errors of regression parameter estimates, I apply cluster-robust standard errors at the country-year level[6].

[6]Following the seminal paper by Bertrand, Duflo and Mullainathan (2004) on difference-in-differences estimates, consideration was taken on the appropriate correction for clustering given that there are only 15

Weighted estimates are used to estimate causal effects to correct for heteroskedastic error terms and to achieve more precision of the estimates (Solon, Haider and Wooldridge, 2015)[7]. I apply the weighting variable for women aged 15-49 years, the common individual-level weighting variable for the three main data sources[8]. To account for the pooled survey data across countries and years, I denormalize the weighting variable using data from the United Nations World Population Prospects data to determine the population of women aged 15-49 for each country and survey year (United Nations, 2016)[9].

Appendix Table C1 evaluates the inclusion of the components of Equations (1) and (2) and displays the estimates for the impact of the ACTs subsidy on children with fever taking ACTs in the private sector. Each panel and column combination is a different regression. In panel A, the pooled participating country analysis, entries are the coefficient β from Equation (1). Panel B displays the β_i coefficients from Equation (2), the separated country analysis. Focusing on panel A, in column 1 I include country and year fixed effects; I observe a statistically significant, positive association (the intended effect) between the pooled set of countries participating in the ACTs subsidy and ACTs taken in the private sector. The

countries and the policy change occurred at the national level. To address this challenge, regressions were run with different clustering options (i.e., cluster on country vs. country-year) to determine which method resulted in smaller standard errors. Clustering on country-year resulted in smaller standard errors and has been applied to all regressions. Cameron, Gelbach and Miller (2008) and Cameron and Miller (2015) expand on the work by Bertrand, Duflo and Mullainathan (2004) and express concern that standard asymptotic tests can over-reject when there are few (5-30) clusters. The authors suggest an alternative clustering method for standard errors referred to as the wild cluster bootstrap. They provide evidence that bootstrapping to obtain asymptotic refinement leads to improved inference for OLS estimation with cluster-robust standard errors when there are few clusters.

[7]Survey weights were used to make the sample representative of the target population when estimating population summary statistics (Solon, Haider and Wooldridge, 2015).

[8]There are three primary sources of data: DHS, MIS, and MICS surveys. For the DHS and MIS surveys, I merge the birth recode (BR), child recode (KR), and household recode (HR) files. Using the Standard DHS for Ghana in 2014 as an example, variable "v005" represents the women's weight in the BR and KR files. Therefore, all children on the BR and KR files that come from the same woman (their mother) have the same weight variable v005 response. The MICS data are different from the DHS and MIS survey data in that they provide the women's weight and the child's weight as separate variables. Since I am pooling together data from DHS, MIS, and MICS, I use the common weighting variable across the three surveys, women's weight.

[9]Following the recommendations for statistical analyses provided by the survey forum, I applied the following equation to generate the denormalized weighting variable: denormalized weight = women's weight x (total females age 15-49 in the country at the time of the survey) / (number of women age 15-49 interviewed in the survey).

inclusion of the demographic characteristics in column 2 leads to a slight a reduction in the standard error compared to that in column 1. Column 3 shows the impact of including the malaria prevalence factors. I assess the sensitivity of my results to the inclusion of the country-specific linear trend and country-specific quadratic trend in columns 4 and 5. The concern is that countries that adopt the ACTs subsidy might have different pre-subsidy trends than countries that do not adopt the ACTs subsidy. My sample was too small resulting in not enough power to include the either time trend into the specification and obtain meaningful results. Last, in column (6), I modify the specification in column (3) to have no weights applied to the regression. The results illustrate that without weights, I underestimate the true effect of the ACTs subsidy. Column (3) is the preferred specification that is used for all analyses in this paper.

An event study using Equation (3) was applied to assess changes over time in treatment seeking behavior.

$$\mathbf{Y}_{ct} = \alpha + \sum_{k=1}^{N} \beta I_{ik} * ACTsubsidy_c + \eta \mathbf{X}_{ct} + \lambda_c + \mu_t + \epsilon_{ct} \tag{3}$$

where the interaction term in Equation (3) is $\sum_{k=1}^{N} I_{ik}$*ACTsubsidy$_c$ and the coefficient of interest is β_{ik}. I_{ik} is a set of binary variables that represents years 2006, 2007, ... , and 2016. To clarify, if I_{ik} is year 2006, then the variable is equal to 1 if year t equals year 2006. ACTsubsidy$_c$ is an binary variable equal to 1 if country c elected to participate in the ACTs subsidy. The base level is set to year 2010, the year immediately prior to the effective period of the ACTs subsidy. The definition of the remaining variables in Equation (3) matches that of Equations (1) and (2).

5.1 Parallel Trends Assumption

The key identifying assumption of the DD design is that treatment seeking behavior trends would be the same for countries participating in the ACTs subsidy and the control

countries in the absence of the policy change.

To assess the validity of the parallel trends assumption, I first compare the pre-ACTs subsidy trends in Figure 2, which illustrates the adjusted means for the treatment seeking behavior trends for the outcomes using Equation (1). Visual inspection shows a deviation from the trend in years 2008, 2009, and 2010. The deviations are most likely due to only one participating country having survey data collected for that year. Focusing on the countries participating in the ACTs subsidy, only Nigeria reported data in 2008, Uganda in 2009, and Nigeria in 2010. Refer to Appendix Figure B1 for the number of years of data collected for each country.

I more formally test for the equality of the pre-ACTs subsidy trends using the event study method. In Equation (3), I estimate regressions that interact the treatment group indicator with the year indicator variables (omitting year 2010 as the reference year). I jointly test the null hypothesis that all pre-2011 interaction terms are equal to 0 using an F-test and display the results of the event study in Table 1. If the results showed that treatment seeking behavior was changing for the ACTs subsidy group relative to the control group before the the ACTs subsidy became effective, then that would suggest the DD estimate is biased. The first five rows of the event study results (ACTsubsidy*Year 2016, ACTsubsidy*Year 2015, ..., ACTsubsidy*Year 2011) represent the treatment seeking behavior effects for which to compare the prior trends[10].

For all three outcomes, the p-value for the F-tests indicate that we cannot reject the F-test that all pre-2011 interaction coefficients are equal to zero. Overall, these results are evidence that the key identifying assumption of the DD design is satisfied.

[10]ACTsubsidy*Year 2012 is ommitted from the output in Table 1 because there were no participating countries with survey data in year 2012.

6 Empirical Results

Table 3 displays the main results[11]. The results tables contain two panels; both panels utilize the full sample of 110,676 children under five years of age with fever in the last two weeks. Panel A displays the results for the pooled participating country analysis from Equation (1), representing the "overall effect" of the ACTs subsidy on each outcome. Panel B shows the results for the participating countries analyzed separately using Equation (2).

The ACTs subsidy was associated with a statistically significant[12] 6.8 percent *increase* in children with fever taking ACTs in the private sector. To complement this result, the ACTs subsidy was associated with a marginally significant 9.0 percent *decrease* in children with fever taking non-ACTs (i.e., lesser effective antimalarial monotherapies) from any sector. This combination of results is the intended policy response which confirms that the financing models are achieving their objectives.

In addition, the ACTs subsidy had no statistically significant effect on children with fever taking ACTs in the public sector. This implies that there is not a substitution effect taking place from treatment obtained in the public sector to the private sector. The impact of the ACTs subsidy was in the private sector, which is the sector targeted by the policy change.

If the ACTs subsidy is effective in the long-term, then the incidence of malaria (i.e., reporting a fever on the survey) should decrease. There are two mechanisms for this to produce the intended effect over time. First, if there is an increase in the use of ACTs to treat uncomplicated malaria, then the mosquito vector will have fewer hosts to feed off of since the infected children will have a faster clinical and parasitological response. The decrease in children taking non-ACTs is important as this will cause a decrease in treatment failure from lesser effective antimalarial monotherapies, because these treatments are prone to drug resistance. Therefore, there will be a decrease in malaria incidence due to recrudescence.

Focusing on panel B, Ghana and Nigeria showed no significant effect for the outcomes.

[11] Appendix Tables C2-C3 display the main results along with the coefficients and standard errors for all covariates

[12] At the 5 percent level.

Therefore, the overall impact of the subsidy described above is being driven by changes in treatment seeking behavior in Uganda. The country-specific results are supported by Figure A1. Among the three participating countries, Uganda had the largest difference in prices of ACTs to the consumer in the post-subsidy period when comparing prices of ACTs in private sector outlets less the prices of ACTs in public sector outlets.

6.1 Changes Over Time

There are challenges to implementing the policy change which may cause a delay in the response to the ACTs subsidy. The country-specific estimates for the amount of ACTs to be purchased, the distribution chain from the manufacturer to the various outlets, and enforcement of price setting is complex. These challenges have the potential to be addressed with sufficient time.

The event study results in Table 1, column 1 shows that children with fever taking ACTs in the private sector did not start to increase in comparison to the base level until three years after the policy change became effective. The greatest increase was observed in years 2013 and 2015. The event study provides evidence for why this paper is an improvement over previously published papers that could only study the short-term effect of the ACTs subsidy due to a shorter post-subsidy period used for the analysis.

In column 2, I focus on year 2011. In year 2011, children with fever taking ACTs in the public sector had a statistically insignificant, yet meaningful result. Year 2011 was the only year that the financing mechanisms targeted both the public and private sectors for subsidized ACTs, hence the positive effect in the public sector.

In column 3, I find that children with fever taking non-ACTs from any sector experienced a steady decline after the introduction of the ACTs subsidy, but the coefficients were only statistically significant in years 2013 and 2014. These results imply that treatment of malaria with lesser effective antimalarial monotherapies (i.e., non-ACTs) are decreasing over time, but not along the sharp decline to indicate that market share of these drugs have been

replaced by ACTs.

6.2 Heterogeneous Treatment Effects

I checked for heterogeneous treatment effects for the outcomes by using the same DD framework in Equations (1) and (2) with a restricted universe. Tables 4-6 show the results for the outcomes generated by regressions for sub-populations that have the potential to be target groups for the ACTs subsidy: the indigent population[13], the non-indigent population[14], households in rural areas, and households in urban areas.

Two noteworthy results are observed. First, for children with fever taking ACTs in the private or public sector (Tables 4-5, panel A), positive, statistically significant effects were only observed for the non-indigent and urban populations. This can be explained by indigent and rural residents have more challenges to seeking treatment in public and private sector outlets due their budget constraint and the distance they are located from these sources. Residents in urban areas have fewer geographic limitations before and after the subsidy in comparison to the rural group.

A second important observation is that the non-indigent population has coefficients of much larger magnitude than that of the indigent population in Tables 4-5, panel A. This suggests that the policy change was not effective at setting the price of the subsidized ACTs low enough so that the drugs are affordable to families of varying socioeconomic status.

In addition, Table 6, panel A shows that no statistically significant effect is observed for children with fever taking non-ACTs in any sector. This implies that when the special populations are analyzed separately, the impact on lesser effective monotherapies is less pronounced.

[13]Indigent population defined as children from households with a wealth index classified as poorer or poorest.

[14]Non-indigent population defined as children from households with a wealth index classified as middle, richer, or richest.

7 Falsification Tests

I conducted two falsification tests to assess the internal validity of my results. First, I estimated models in which I assume falsely that the ACTs subsidy took place prior to year 2011, using data from the period before to the ACTs subsidy. In Table 7, the universe is restricted to years 2006-2010 and I re-estimate Equations (1) and (2) by assuming a placebo policy implementation date in the interaction term (e.g., ACTsubsidy*Post2007) for the for the ACTs subsidy effective date[15].

I examined the results of the placebo estimates and compared them to those in my results for the overall impact of the expansion reported in Table 3. The falsification test in Table 7 generated statistically insignificant results with different magnitudes from those of Table **??**. This indicates that there is no evidence that the changes in treatment seeking behavior for children with fever are due to differential trends between the treatment and control states in omitted variables, or other potential sources of bias.

For the second falsification test, I returned to the full universe of data, years 2006-2016. A salient result is observed in Table 8. The ACTs subsidy had no statistically significant effect on children *without* fever taking ACTs from any sector. All coefficients are close to zero. ACTs are recommended for the treatment of uncomplicated malaria caused by the *P. falciparum* parasite and are not recommended to treat other illnesses. My results in Table 8 imply that communication messages and retailer training has been effective on the appropriate use of ACTs.

8 Limitations

In the main results discussion, I established that overall the ACTs subsidy made a significant impact on ACTs taken in the private sector; no substitution effect was observed in

[15]In Table 7 panel B, the results for Ghana are excluded because Ghana only has one year of data in years 2006-2010, making it not possible to conduct the DD analysis on Ghana. Therefore, Ghana was excluded from this analysis.

the public sector. Ideally, I would want to evaluate the impact the ACTs subsidy had on the specific private sector sources of treatment: hospital/clinic, pharmacy, dispensary, chemist, doctor, mobile clinic, community health worker, shop, traditional practitioner, drug peddler, friend, church, or other private source. The policy change made ACTs available for purchase in private sector shops in an over-the-counter format for the first time. If ACTs were affordable and available in private shops, then I would expect the effect of the ACTs subsidy to be greater for private shops than traditional sources of care in the private sector. Unfortunately, the number of children reporting private sector shops as their source of treatment was very small in the pre- and post-subsidy period, not allowing for enough power to conduct a DD analysis.

General limitations of cross-sectional surveys include data that were collected at a defined point in time; individuals were not followed over time. In addition, cross-sectional surveys are subject to recall bias. For example, the mother/caretaker was asked if the child had fever in the last two weeks, what treatment the child took for fever, and the source of treatment. These responses are all subject to recall bias. Recall bias in this context is not related to treatment; the ACTs subsidy was a nationwide intervention. However, the outcome may be an underestimate from the true effect of the ACTs subsidy if mothers/caretakers underreport the treatment taken and source of treatment. Specific to the data sources I used, there was an unbalanced panel of survey years (Appendix Table B1). Last, the surveys I used did not collect specimens from all children to assess if they had a positive diagnostic test for malaria. Therefore, treatment for malaria is based on the household's subjective assessment of the child's fever that may or may not be malaria.

Selection bias may occur in terms of the decision to use the ACTs subsidy for treatment of malaria. For example, once a child has a fever, if the mother/caretaker decides to either seek treatment or do nothing. It is possible that the children for whom treatment is sought are sicker than the children from households who do nothing to treat the child's fever. The rationale is that households that decide to seek treatment may subjectively assess the child's

malaria illness as severe or life-threatening, justifying the decision to invest resources on treatment (prior to the subsidy, treatment was free in the public sector in most countries). In this case, children in the ACTs subsidy countries may be sicker than the control group (i.e., if the household believes the child's malaria is severe enough to warrant spending money on ACTs in the private sector rather than seeking them for free in the public sector). The true direction of the bias is unknown since there are alternative scenarios that could result in the participating countries group to be healthier than the control group. To address the concern of selection bias, separate analyses were run on four target populations expected to be most affected by the ACTs subsidy. The results for heterogeneous treatment effects in Table 4 are similar to the main results in Table 3 column 1, suggesting that selection bias did not have an impact on taking ACTs in the private sector, the treatment and sector targeted by the financing mechanism.

A final challenge was the selection of an appropriate set of control countries[16]. There is no perfect solution to this challenge, but selection criteria were enforced to include countries as similar as possible to the participating countries. For example, all countries had to be located in malaria-endemic, sub-Saharan Africa where *Plasmodium falciparum* is prevalent. In addition, all countries had to have similar malaria transmission intensity rates and access to other malaria control interventions (e.g., insecticide treated bed nets). Control variables for malaria prevalence factors were included to account for surveys collected at different times of year. Country fixed effects were included in all regressions to remove between group variation.

9 Conclusion

Overall, the ACTs subsidy achieved two of its objectives that can be assessed using these data. ACTs taken in the private sector increased and treatment with lesser effective

[16]The scientific control method (SCM) could not be implemented to construct a synthetic control group because there was not a balanced panel of country-years.

monotherapies from any sector decreased for countries participating in the subsidy. There was no effect on ACTs taken in the public sector, indicating no substitution effect from the public to the private sector. The private sector outlets effected in order of magnitude were: hospitals/clinics, pharmacies, and shops. This is surprising as the theoretical model predicted that private sector pharmacies and clinics would see the greatest effect from the policy change. Last, there was significant effect heterogeneity observed among the three countries participating in the analysis. Ghana showed no significant response to the policy change, whereas Uganda had the strongest response for the two main outcomes.

To explain these findings, there were differences in the price of ACTs in the public and private sector before and after the subsidy to the consumer among the four participating countries. In addition, an independent evaluation team (IET) conducted a pre-intervention baseline survey and an endline survey 15 months after ACTs were available in country for a sample of the outlets participating in the Private Sector Co-Payment Mechanism (AMFm IET, 2012). Below, I provide findings from the IET to support my results[17].

Ghana. My results show no statistically significant effect on ACTs taken in the private or public sector as well as no effect on non-ACTs taken in any sector in Ghana. This may be explained by the post-subsidy price of ACTs in the public sector of US $0.94 compared to the price in the private sector, US $1.13. Ghana was the only participating country to not provide ACTs for free in the public sector before and after the subsidy. The IET report confirmed that at 15 months post the intervention start date, there was no increase of quality-assured ACTs *availability* in the public sector. However, the IET reported an increase in *availability* in the private outlets from non-ACTs to quality-assured ACTs. Last, the IET reported that the ACTs subsidy communication campaigns and training of health workers did not commence until six months after ACTs arrived in Ghana. This may also contribute to why some households did not change their treatment seeking behavior.

[17]AMFm IET (2012) differentiates between quality-assured ACTs and non-quality assured ACTs. I preserve the distinction on quality assurance when referring to the IET results. However, my data sources do not collect information on the quality assurance of ACTs. The results in this report are based on surveys administered during 2011-2012.

Nigeria. My results show no statistically significant effect on ACTs taken in the private or public sector as well as no effect on non-ACTs taken in any sector in Nigeria. The IET reports an increase in the *availability* of quality assured ACTs in private sector outlets, but also found a higher proportion of non-ACTs *available* in the same outlets. Challenges to promoting ACTs over non-ACTs in the private sector were thought to be due to price setting of the comparison drugs and a delay of six months for the implementation of supporting interventions to promote ACTs.

Uganda. Uganda achieved the intended response to the subsidy in my analysis. Among children with fever, ACTs taken in the private sector increased and non-ACTs taken from any sector decreased. Although these results are admirable, the IET's findings show that they did not come without challenges. There were delays with the distribution chain, no communication campaigns as of November 2011, and that the price of ACTs in the private, for-profit sector was three times that of alternative therapies. More information is needed on what is driving the overall success of the ACTs subsidy in Uganda so that other countries may learn from their methods.

In conclusion, two of the testable objectives of the policy change were achieved, but the response within each participating country was mixed. Country governments considering to offer subsidized ACTs in the future need to consider the existing price of ACTs and alternative therapies in both the public and private sector to ensure the subsidy would be sufficient to change treatment seeking behavior. In addition, mechanisms must be in place to assure availability and affordability of ACTs once the subsidy is active. Supporting interventions must implemented in a timely manner to inform the public of ACTs prices and availability.

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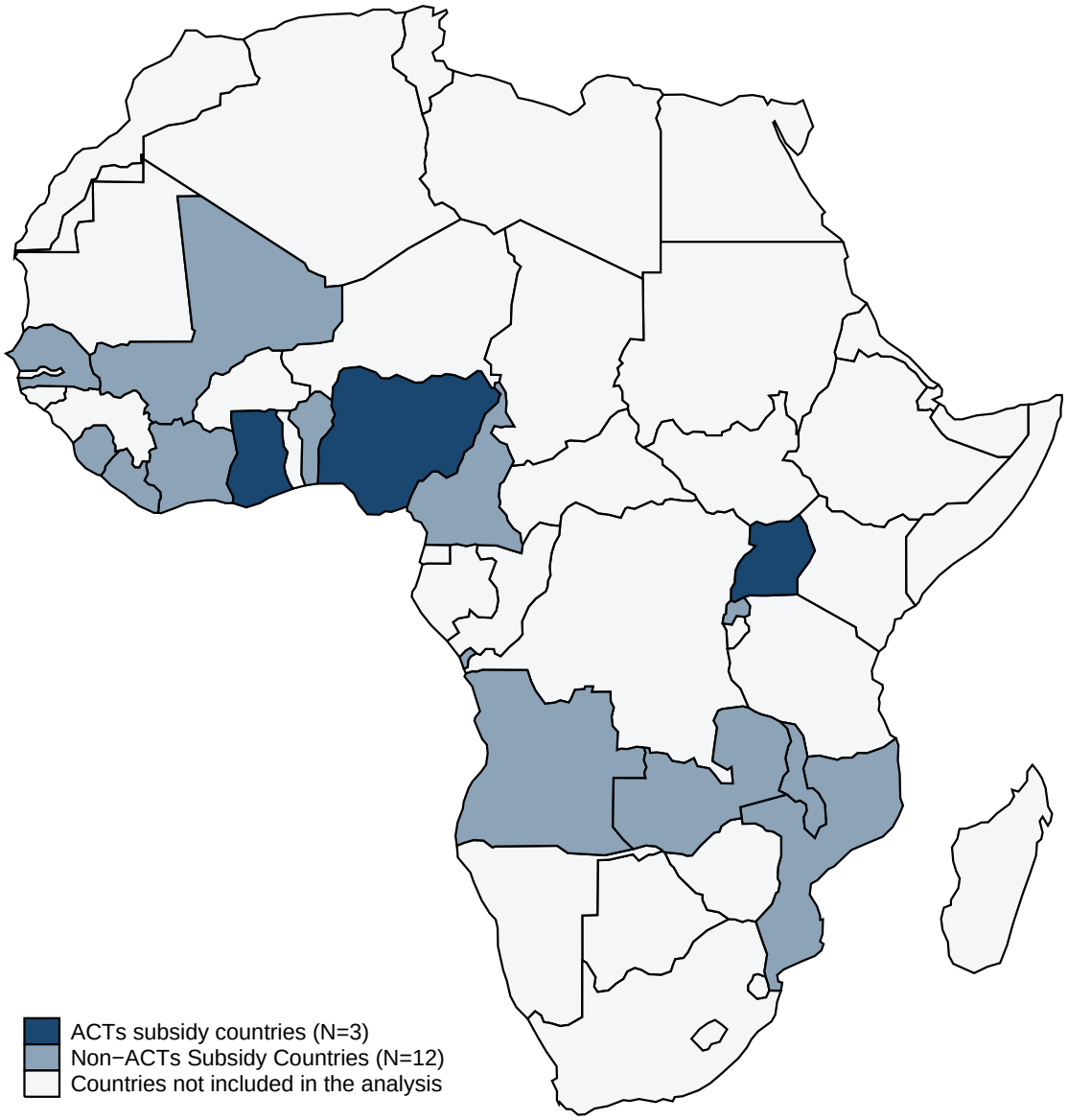
Figures and Tables

Figure 1: Map of Countries Included in the Analysis

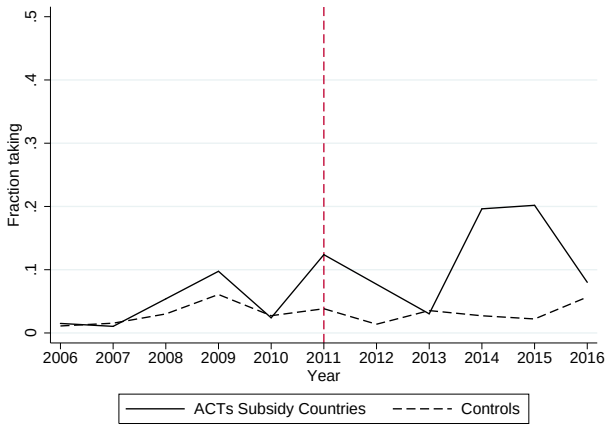


Notes: ACTs subsidy countries include Ghana, Nigeria, and Uganda. Non-ACTs subsidy countries include Angola, Benin, Cameroon, Cote d'Ivoire, Liberia, Malawi, Mali, Mozambique, Rwanda, Senegal, Sierra Leone, and Zambia. Kenya, Niger, and Tanzania had data pre- and post- the subsidy period, but did not have any data collected during the years of participation in the financing models. Therefore, Kenya, Niger, and Tanzania were excluded from all analyses. Namibia, Swaziland, and Zimbabwe were excluded from the analysis because malaria transmission in these countries is very low and not comparable to the countries participating in the ACTs subsidy. All other countries excluded from the analysis due to data availability pre- and post- the ACTs subsidy.

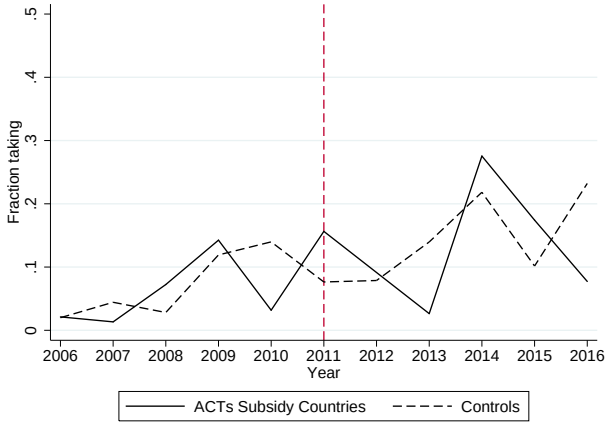
Source: Map generated by the author using a public domain shape file from naturalearthdata.com.

Figure 2: Trends in Treatment Seeking Behavior

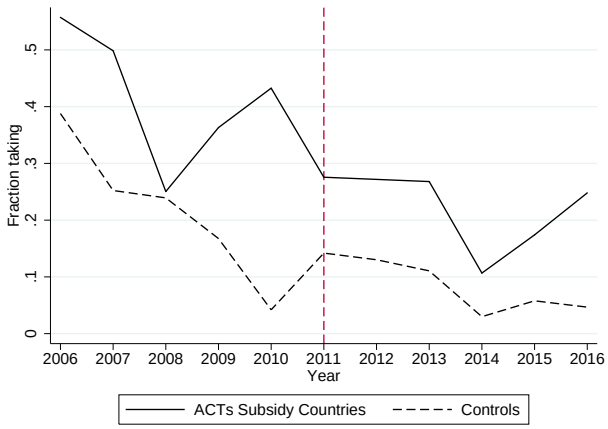
(a) Took ACTs in Private Sector



(b) Took ACTs in Public Sector



(c) Took Non-ACTs in Any Sector



Notes: Observations are children under 5 years of age reporting a fever in the last two weeks. *Source:* Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey data for years 2006-2016.

Table 1: Event Study Results

	Children ages 0-59 months with fever		
	Took ACTs Private Sector	Took ACTs Public Sector	Took Non-ACTs Any Sector
ACTsubsidy*Year 2016	0.018	0.055	-0.099
	(0.039)	(0.076)	(0.114)
ACTsubsidy*Year 2015	0.059	0.102	-0.123
	(0.040)	(0.093)	(0.132)
ACTsubsidy*Year 2014	0.027	0.086	-0.183
	(0.040)	(0.057)	(0.085)**
ACTsubsidy*Year 2013	0.031	0.149	-0.199
	(0.030)	(0.046)***	(0.058)***
ACTsubsidy*Year 2011	-0.058	0.014	-0.011
	(0.058)	(0.067)	(0.121)
ACTsubsidy*Year 2009	-0.085	0.074	-0.009
	(0.070)	(0.100)	(0.131)
ACTsubsidy*Year 2008	0.010	0.149	-0.252
	(0.042)	(0.107)	(0.122)**
ACTsubsidy*Year 2007	0.024	0.211	-0.135
	(0.043)	(0.099)**	(0.107)
ACTsubsidy*Year 2006	-0.145	-0.080	0.068
	(0.079)*	(0.077)	(0.107)
p-Value for test that all pre-2011 interaction coefficients are = 0	0.2382	0.1210	0.3176
Country-Years	71	71	71

Notes: * .10 ** .05 *** .01 significance levels. XXX - No data were collected for the three treatment countries in year 2012. Each column combination represents a separate regression. Panel A coefficients are reported from the interaction term $ACTsubsidy_c$*$Post2010_t$ in Equation (1). All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. *Source*: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Table 2: Summary Statistics of Outcomes & Covariates

	Years 2006-2010				Years 2011-2016			
	ACTs Subsidy Countries		Control Countries		ACTs Subsidy Countries		Control Countries	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcomes								
Took ACTs in Private Sector	.02	[.16]	.02	[.13]	.09	[.28]	.04	[.18]
Took ACTs in Public Sector	.04	[.2]	.07	[.25]	.1	[.3]	.18	[.38]
Took Non-ACTs in Any Sector	.42	[.49]	.26	[.44]	.25	[.43]	.08	[.28]
Covariates								
Characteristics of the Head of Household								
Age in years	40.03	[12.18]	40.88	[13.77]	40.72	[12.5]	40.49	[13.98]
Female	.15	[.36]	.18	[.38]	.14	[.34]	.21	[.41]
Characteristics of the Mother/Caretaker								
Age in years	29.93	[7.08]	28.62	[7.02]	29.43	[7.11]	28.5	[7.01]
Years of education	4.45	[4.72]	2.86	[3.5]	4.34	[4.64]	3.69	[3.8]
Characteristics of the Child								
Age in months	27.51	[15.97]	26.28	[15.98]	28.5	[16.12]	27.29	[16.12]
Female	.49	[.5]	.49	[.5]	.49	[.5]	.49	[.5]
Poorest	.27	[.44]	.24	[.43]	.32	[.47]	.26	[.44]
Poorer	.23	[.42]	.23	[.42]	.24	[.43]	.23	[.42]
Richer	.18	[.38]	.19	[.39]	.14	[.35]	.17	[.38]
Richest	.13	[.33]	.13	[.33]	.11	[.31]	.13	[.34]
Rural	.74	[.44]	.76	[.42]	.77	[.42]	.74	[.44]
Malaria Prevalence Factors								
Malaria trans. intensity	.41	[.16]	.3	[.18]	.36	[.15]	.23	[.17]
Avg. mo. precipitation	132.36	[114.52]	59.51	[69.43]	77.94	[67.35]	135.06	[109.02]
Countries	3		12		3		12	

Notes: The pre-ACTs subsidy period includes years 2006-2010; the post-ACTs subsidy period includes years 2011-2016. Columns (1), (3), (5), and (7) display the pre- and post-ACTsubsidy treatment seeking behavior outcomes for the participating versus non-participating countries. Standard deviations are in brackets. Observations are children under 5 years of age reporting a fever in the last two weeks.

Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Table 3: Main Results: Impact on Treatment Seeking Behavior

	Children ages 0-59 months with fever		
	Took ACTs Private Sector	Took ACTs Public Sector	Took Non-ACTs Any Sector
Panel A. Pooled Participating Country Analysis			
ACTs subsidy*Post 2010	0.068	0.045	-0.090
	(0.034)**	(0.037)	(0.048)*
Country-Years	71	71	71
Panel B. Participating Countries Analyzed Separately			
ACTs subsidy GH*Post 2010	0.004	0.011	-0.026
	(0.038)	(0.068)	(0.092)
ACTs subsidy NG*Post 2010	0.021	0.017	-0.062
	(0.019)	(0.052)	(0.067)
ACTs subsidy UG*Post 2010	0.191	0.114	-0.187
	(0.046)***	(0.056)**	(0.068)***
Country-Years	71	71	71
Specification for All Panels			
All covariates	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes

Notes: * .10 ** .05 *** .01 significance levels. XXX - No data were collected for the three treatment countries in year 2012. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2). All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. *Source*: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Table 4: Impact on Target Groups for the Outcome: Took ACTs in Private Sector

	Children ages 0-59 months with fever restricted to:			
	Indigent	Non-Indigent	Rural	Urban
Panel A. Pooled Participating Country Analysis				
ACTs subsidy*Post 2010	0.050	0.086	0.057	0.064
	(0.031)	(0.033)**	(0.032)*	(0.037)*
Country-Years	71	71	71	71
Panel B. Participating Countries Analyzed Separately				
ACTs subsidy GH*Post 2010	-0.005	0.008	-0.006	-0.017
	(0.020)	(0.042)	(0.028)	(0.038)
ACTs subsidy NG*Post 2010	-0.001	0.061	0.011	0.057
	(0.022)	(0.032)*	(0.019)	(0.047)
ACTs subsidy UG*Post 2010	0.180	0.187	0.196	0.158
	(0.043)***	(0.045)***	(0.039)***	(0.033)***
Country-Years	71	71	71	71
Specification for All Panels				
Full Covariates	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Notes: * .10 ** .05 *** .01 significance levels. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2).

Column 1 displays the main results for the sample restricted to children from the "poorest" and "poorer" families based on the wealth index. Column 2 displays the main results for the sample restricted to children from the "middle," "richer," and "richest" families based on the wealth index. Columns 3 and 4 display the main results for the sample restricted to children from rural and urban places of residence, respectively.

All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. Standard errors are in parentheses.

Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data: years 2006-2016.

Table 5: Impact on Target Groups for the Outcome: Took ACTs in Public Sector

	Children ages 0-59 months with fever restricted to:			
	Indigent	Non-Indigent	Rural	Urban
Panel A. Pooled Participating Country Analysis				
ACTs subsidy*Post 2010	0.003	0.054	0.014	0.062
	(0.042)	(0.030)*	(0.044)	(0.028)**
Country-Years	71	71	71	71
Panel B. Participating Countries Analyzed Separately				
ACTs subsidy GH*Post 2010	0.004	-0.014	0.001	0.001
	(0.077)	(0.068)	(0.081)	(0.046)
ACTs subsidy NG*Post 2010	-0.057	0.047	-0.004	0.062
	(0.061)	(0.043)	(0.064)	(0.050)
ACTs subsidy UG*Post 2010	0.074	0.127	0.054	0.124
	(0.049)	(0.052)**	(0.063)	(0.041)***
Country-Years	71	71	71	71
Specification for All Panels				
Full Covariates	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Notes: * .10 ** .05 *** .01 significance levels. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2).
Column 1 displays the main results for the sample restricted to children from the "poorest" and "poorer" families based on the wealth index. Column 2 displays the main results for the sample restricted to children from the "middle," "richer," and "richest" families based on the wealth index. Columns 3 and 4 display the main results for the sample restricted to children from rural and urban places of residence, respectively.
All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. Standard errors are in parentheses.

Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data: years 2006-2016.

Table 6: Impact on Target Groups for the Outcome: Took Non-ACTs in Any Sector

	Children ages 0-59 months with fever restricted to:			
	Indigent	Non-Indigent	Rural	Urban
Panel A. Pooled Participating Country Analysis				
ACTs subsidy*Post 2010	-0.046	-0.075	-0.066	-0.010
	(0.077)	(0.047)	(0.051)	(0.051)
Country-Years	71	71	71	71
Panel B. Participating Countries Analyzed Separately				
ACTs subsidy GH*Post 2010	0.015	-0.028	-0.035	0.058
	(0.130)	(0.117)	(0.100)	(0.106)
ACTs subsidy NG*Post 2010	0.022	-0.101	-0.026	-0.045
	(0.147)	(0.064)	(0.073)	(0.069)
ACTs subsidy UG*Post 2010	-0.204	-0.094	-0.153	-0.037
	(0.068)***	(0.051)*	(0.055)***	(0.055)
Country-Years	71	71	71	71
Specification for All Panels				
Full Covariates	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Notes: * .10 ** .05 *** .01 significance levels. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2).
Column 1 displays the main results for the sample restricted to children from the "poorest" and "poorer" families based on the wealth index. Column 2 displays the main results for the sample restricted to children from the "middle," "richer," and "richest" families based on the wealth index. Columns 3 and 4 display the main results for the sample restricted to children from rural and urban places of residence, respectively.
All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. Standard errors are in parentheses.

Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data: years 2006-2016.

Table 7: Falsification Test: Placebo Intervention

	Children ages 0-59 months with fever		
	Took ACTs Private Sector	Took ACTs Public Sector	Took Non-ACTs Any Sector
Panel A. Pooled Participating Country Analysis			
ACTs subsidy*Post 2007	0.087	0.084	0.115
	(0.134)	(0.204)	(0.125)
Country-Years	26	26	26
Panel B. Participating Countries Analyzed Separately			
ACTs subsidy NG*Post 2007	0.106	-0.304	1.355
	(0.797)	(1.212)	(0.748)*
ACTs subsidy UG*Post 2007	0.089	0.034	0.273
	(0.183)	(0.279)	(0.172)
Country-Years	26	26	26
Specification for All Panels			
All covariates	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes

Notes: * .10 ** .05 *** .01 significance levels. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2). All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. *Source*: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

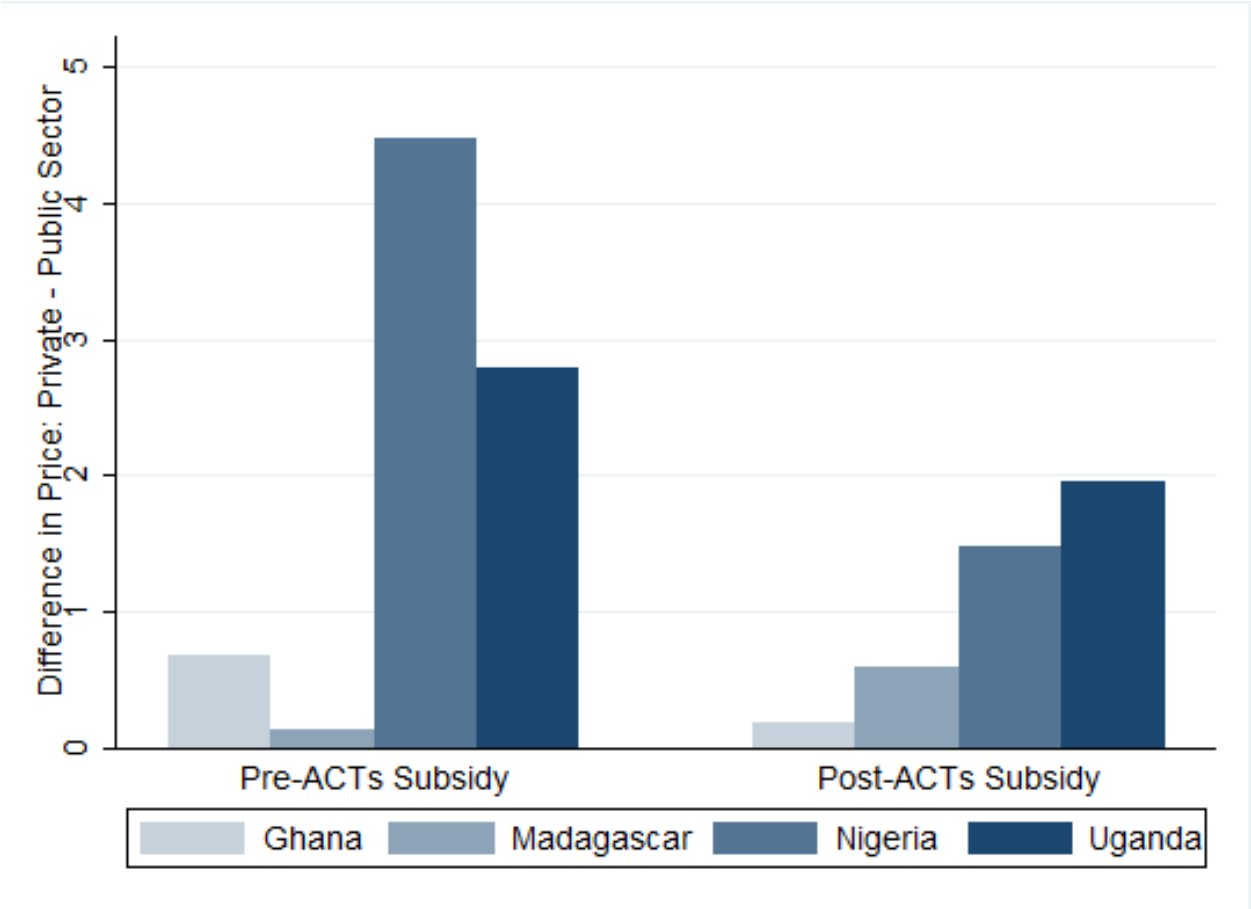
Table 8: Falsification Test: Children Without Fever Taking ACTs

	Children ages 0-59 months **without** fever: Took ACTs in Any Sector
Panel A. Pooled Participating Country Analysis	
ACTs subsidy*Post 2010	0.002
	(0.003)
Country-Years	71
Panel B. Participating Countries Analyzed Separately	
ACTs subsidy GH*Post 2010	-0.004
	(0.004)
ACTs subsidy NG*Post 2010	0.003
	(0.003)
ACTs subsidy UG*Post 2010	0.007
	(0.007)
Country-Years	71
Specification for All Panels	
All covariates	Yes
Country fixed effects	Yes
Year fixed effects	Yes

Notes: * .10 ** .05 *** .01 significance levels. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2). All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. *Source*: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Appendix A: The Price and Source of ACTs

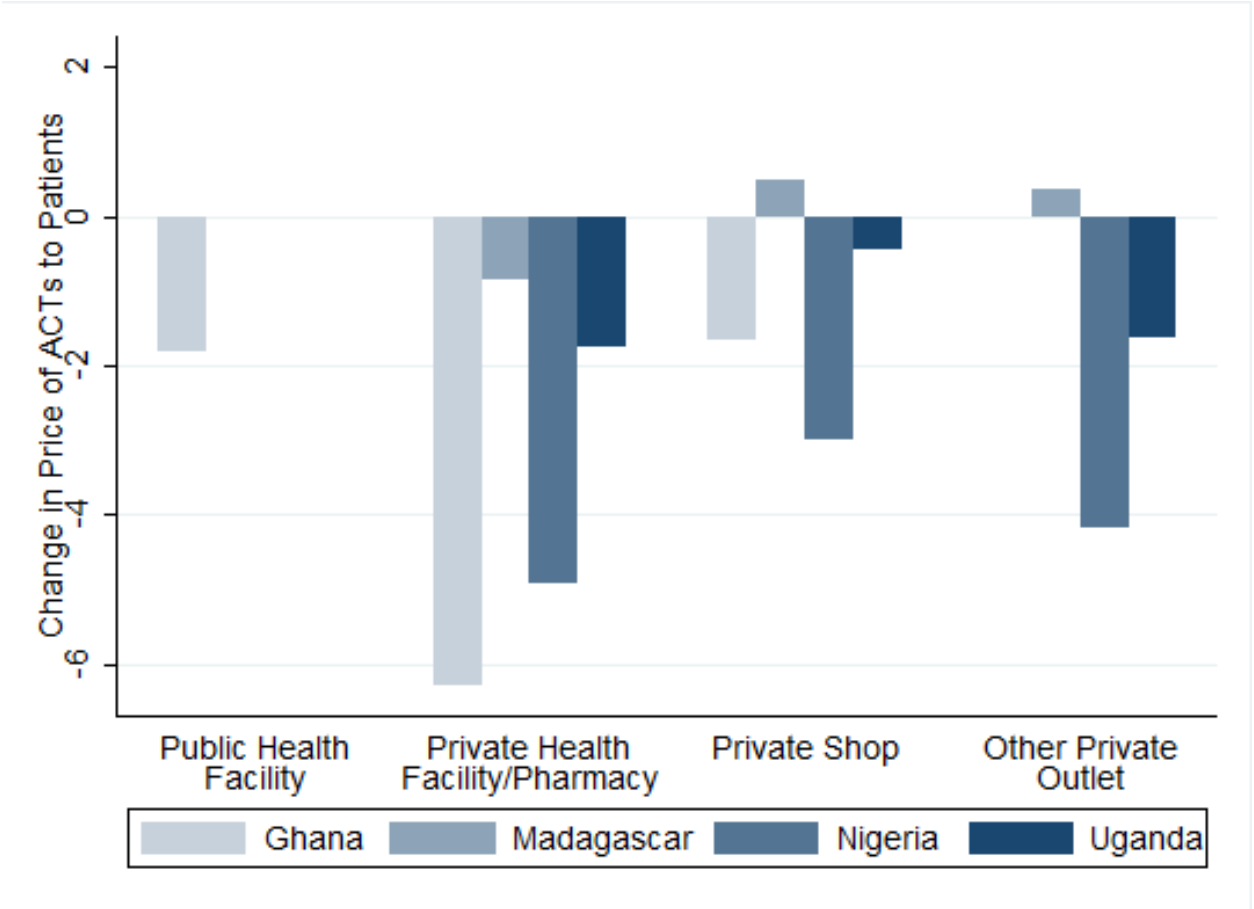
Figure A1: Difference in Private and Public Sector Price of ACTs, Pre- and Post-Subsidy



Notes: Prices reflect the median cost to a household for one adult equivalent treatment dose of quality-assured ACTs in public and private sector outlets. There was free provision of ACTs in the public sector for Madagascar, Nigeria, and Uganda both pre- and post- the ACTs subsidy. Madagascar had an alternative financing mechanism in the pre-subsidy period in the private sector. The pre-subsidy prices were collected in 2009 for Nigeria and in 2010 for Ghana, Madagascar, and Uganda; the post-subsidy prices were collected approximately 15 months after the first financing model was implemented. The recommended retail price for ACTs varies per country. Price data were collected from the Affordable Medicines Facility-malaria independent evaluation outlet surveys. Private sector sources of treatment reflect private, for-profit outlets.

Source: Author's interpretation of data presented in Table 2.3.5 of AMFm IET (2012).

Figure A2: Change in Price of ACTs Post-Subsidy, by Source of Treatment

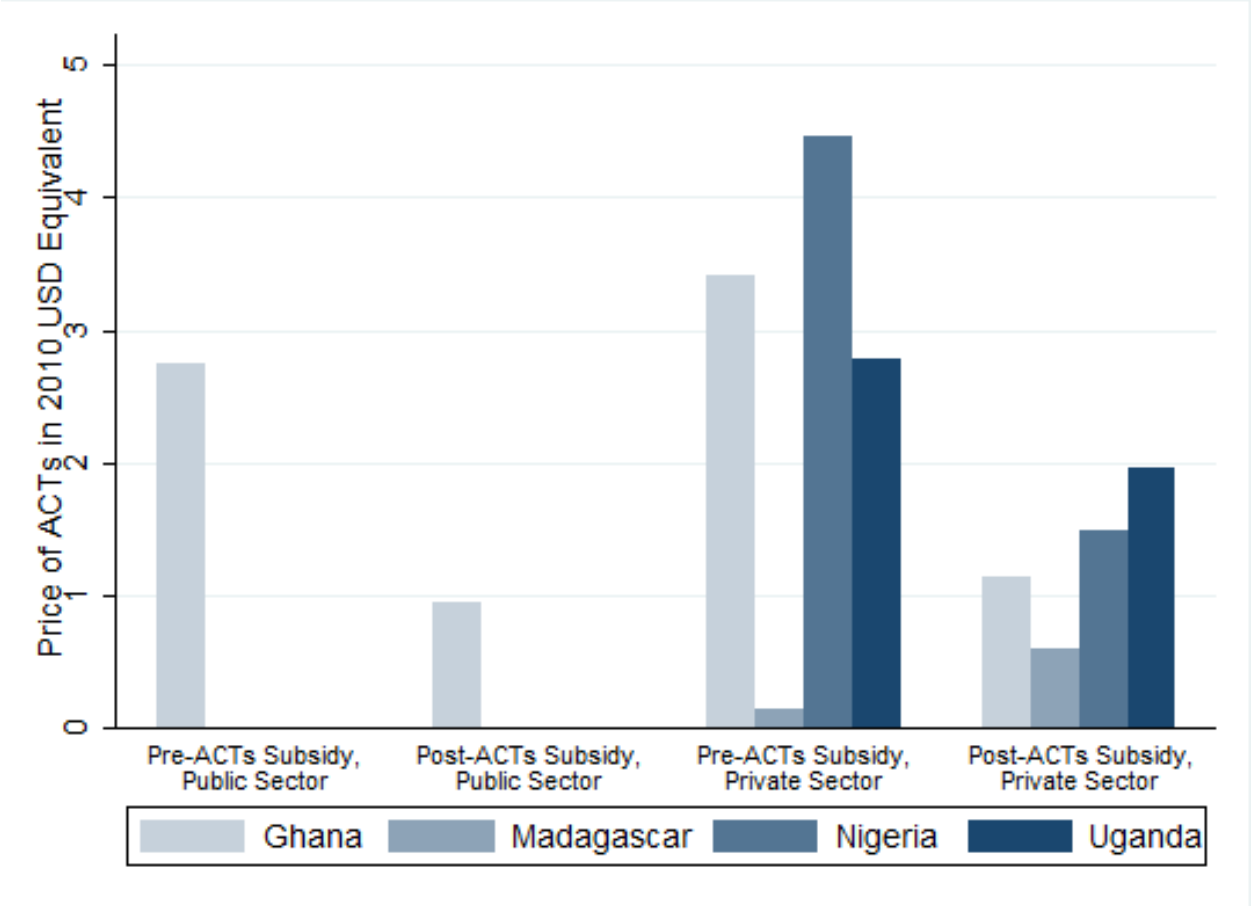


Notes: A value of zero indicates no change in the price of ACTs to people seeking treatment. For example, Madagascar, Nigeria, and Uganda had no change in the price for ACTs offered in public health facilities.

Prices reflect the median cost to a household for one adult equivalent treatment dose of quality-assured ACTs in public and private sector outlets. There was free provision of ACTs in the public sector for Madagascar, Nigeria, and Uganda both pre- and post- the ACTs subsidy. Madagascar had an alternative financing mechanism in the pre-subsidy period in the private sector. The pre-subsidy prices were collected in 2009 for Nigeria and in 2010 for Ghana, Madagascar, and Uganda; the post-subsidy prices were collected approximately 15 months after the first financing model was implemented. The recommended retail price for ACTs varies per country. Price data were collected from the Affordable Medicines Facility-malaria independent evaluation outlet surveys. Private sector sources of treatment reflect private, for-profit outlets.

Source: Author's interpretation of data presented in Table 2.3.5 of AMFm IET (2012).

Figure A3: Prices of ACTs in Public and Private Sector Outlets, Pre- and Post-Subsidy



Notes: A value of zero indicates that ACTs were offered free of charge to people seeking treatment. Madagascar, Nigeria, and Uganda offered ACTs at no cost in the public sector before and after the ACTs subsidy.

Prices reflect the median cost to a household for one adult equivalent treatment dose of quality-assured ACTs in public and private sector outlets. There was free provision of ACTs in the public sector for Madagascar, Nigeria, and Uganda both pre- and post- the ACTs subsidy. Madagascar had an alternative financing mechanism in the pre-subsidy period in the private sector. The pre-subsidy prices were collected in 2009 for Nigeria and in 2010 for Ghana, Madagascar, and Uganda; the post-subsidy prices were collected approximately 15 months after the first financing model was implemented. The recommended retail price for ACTs varies per country. Price data were collected from the Affordable Medicines Facility-malaria independent evaluation outlet surveys.

Source: Author's interpretation of data presented in Figure 10 of AMFm IET (2012).

Appendix B: Survey Datasets Included in the Analysis

Table B1: Survey Datasets Included in the Analysis

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Angola	X	X				X				X	X	5
Benin	X					X	X					3
Cameroon	X					X						2
Cote d'Ivoire	X					X	X					3
Ghana	X					X			X		X	4
Liberia	X	X	X	X		X		X			X	7
Malawi					X		X	X	X	X	X	6
Mali	X						X	X		X		4
Mozambique			X			X						2
Nigeria		X	X		X			X		X	X	6
Rwanda		X	X		X	X		X	X	X		7
Senegal	X		X	X	X	X	X	X	X	X	X	10
Sierra Leone			X					X			X	3
Uganda	X			X		X			X	X		5
Zambia		X						X	X			3
Total	9	5	6	3	4	10	5	8	6	7	7	71

Notes: XXX *Source*: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Table B2: Data Source and Number of Children with Fever, by Country-Year

Country	Year	Survey	Children <5 with Fever	Country	Year	Survey	Children <5 with Fever
Angola	2006	MIS	149	Mozambique	2011	DHS	1,313
Angola	2007	MIS	116	Nigeria	2007	MICS	2,079
Angola	2011	MIS	2,645	Nigeria	2008	DHS	3,962
Angola	2015	DHS	1034	Nigeria	2010	MIS	1,814
Angola	2016	DHS	899	Nigeria	2013	DHS	3,679
Benin	2006	DHS	4,204	Nigeria	2015	MIS	2,622
Benin	2011	DHS	178	Nigeria	2016	MICS	4,108
Benin	2012	DHS	961	Rwanda	2007	DHS	84
Cameroon	2006	MICS	1,087	Rwanda	2008	DHS	986
Cameroon	2011	DHS	1,561	Rwanda	2010	DHS	820
Cote d'Ivoire	2006	MICS	2,133	Rwanda	2011	DHS	511
Cote d'Ivoire	2011	DHS	179	Rwanda	2013	MIS	876
Cote d'Ivoire	2012	DHS	1,477	Rwanda	2014	DHS	519
Ghana	2006	MICS	752	Rwanda	2015	DHS	867
Ghana	2008	DHS	551	Senegal	2006	MIS	1,734
Ghana	2011	MICS	1,618	Senegal	2008	MIS	2,662
Ghana	2014	DHS	824	Senegal	2009	MIS	1,611
Ghana	2016	MIS	889	Senegal	2010	DHS	1,074
Liberia	2006	DHS	180	Senegal	2011	DHS	1,231
Liberia	2007	DHS	1,482	Senegal	2012	DHS	506
Liberia	2008	MIS	245	Senegal	2013	DHS	640
Liberia	2009	MIS	1,353	Senegal	2014	DHS	761
Liberia	2011	MIS	1,605	Senegal	2015	DHS	1,082
Liberia	2013	DHS	2,203	Senegal	2016	DHS	912
Liberia	2016	MIS	1,129	Sierra Leone	2008	DHS	1,262
Malawi	2010	DHS	6,279	Sierra Leone	2013	DHS	2,846
Malawi	2012	MIS	676	Sierra Leone	2016	MIS	1,606
Malawi	2013	MICS	1,410	Uganda	2006	DHS	3,082
Malawi	2014	MIS	5,788	Uganda	2009	MIS	1,652
Malawi	2015	DHS	3,461	Uganda	2011	DHS	2,859
Malawi	2016	DHS	1,211	Uganda	2014	MIS	935
Mali	2006	DHS	2,091	Uganda	2015	MIS	477
Mali	2012	DHS	592	Zambia	2007	DHS	1,033
Mali	2013	DHS	207	Zambia	2013	DHS	1,662
Mali	2015	MIS	2,104	Zambia	2014	DHS	1,073
Mozambique	2008	MICS	2,463				

Notes: Surveys are not administered in consecutive years for each country. In some cases, children were not sampled from every country region within a survey year. Malaria transmission intensity is dependent on the time of year the survey was collected. ITN is defined as ownership of an insecticide-treated bed net. IRS is defined as indoor residual spraying in the last 12 months. Countries may elect to have no IRS for specific years.

Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Appendix C: Difference-in-Differences Results

Table C1: Evaluating Difference-in-Differences Model Components

	Children ages 0-59 months with fever Took ACTs in Private Sector					
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Pooled Participating Country Analysis						
ACTs subsidy*Post 2010	0.068	0.062	0.068	-0.009	-0.009	0.063
	(0.031)**	(0.032)*	(0.034)**	(0.056)	(0.056)	(0.026)**
Country-Years	71	71	71	71	71	71
Panel B. Participating Countries Analyzed Separately						
ACTs subsidy GH*Post 2010	0.002	0.002	0.004	-0.148	-0.148	0.004
	(0.031)	(0.037)	(0.038)	(0.072)**	(0.072)**	(0.038)
ACTs subsidy NG*Post 2010	0.023	0.017	0.021	0.026	0.026	0.021
	(0.018)	(0.015)	(0.019)	(0.045)	(0.045)	(0.019)
ACTs subsidy UG*Post 2010	0.200	0.190	0.191	0.058	0.058	0.191
	(0.036)***	(0.041)***	(0.046)***	(0.049)	(0.049)	(0.046)***
Country-Years	71	71	71	71	71	71
Specification for All Panels						
Demographic Characteristics	No	Yes	Yes	Yes	Yes	Yes
Malaria Prevalence Factors	No	No	Yes	Yes	Yes	Yes
Country linear time trend	No	No	No	Yes	No	No
Country quadratic time trend	No	No	No	No	Yes	No
Weighted data	Yes	Yes	Yes	Yes	Yes	No
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * .10 ** .05 *** .01 significance levels. Each panel and column combination represents a separate regression. Panel A coefficients are reported from the interaction term ACTsubsidy_c*Post2010_t in Equation (1), where the ACTsubsidy variable is equal to 1 if country equals Ghana, Nigeria, or Uganda. Panel B coefficients are reported from the interaction terms ACTsubsidyGH_c*Post2010_t, ACTsubsidyNG_c*Post2010_t, and ACTsubsidyUG_c*Post2010_t in Equation (2).

The models vary by the inclusion of covariates. The covariates include characteristics of the head of household, mother/caretaker, and child; and malaria prevalence factors. All regressions have denormalized sample weights and standard errors clustered at the country-year level. Observations are children under 5 years of age reporting a fever in the last two weeks. Standard errors are in parentheses.

Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Table C2: Treatment Seeking Behavior: Pooled Participating Country Analysis

	Children ages 0-59 months with fever		
	Took ACTs Private Sector	Took ACTs Public Sector	Took Non-ACTs Any Sector
ACTs subsidy*Post 2010	0.068	0.045	-0.090
	(0.034)**	(0.037)	(0.048)*
Characteristics of the Head of Household			
Age in years	0.001	-0.001	-0.003
	(0.004)	(0.005)	(0.007)
Female	-0.076	-0.122	-0.475
	(0.210)	(0.289)	(0.379)
Characteristics of the Mother/Caretaker			
Age in years	-0.003	0.033	0.026
	(0.012)	(0.020)	(0.033)
Years of education	0.011	0.031	-0.018
	(0.005)**	(0.011)***	(0.019)
Characteristics of the Child			
Age in months	-0.001	-0.000	0.011
	(0.004)	(0.007)	(0.009)
Female	-0.220	-0.108	0.078
	(0.252)	(0.428)	(0.580)
Poorest	0.014	-0.248	0.791
	(0.298)	(0.433)	(0.561)
Poorer	0.292	0.757	-0.843
	(0.360)	(0.451)*	(0.592)
Richer	0.093	0.229	0.293
	(0.315)	(0.490)	(0.638)
Richest	0.020	-0.005	0.201
	(0.250)	(0.332)	(0.420)
Rural	-0.005	0.051	-0.119
	(0.069)	(0.125)	(0.174)
Malaria Prevalence Factors			
Malaria endemicity	-0.205	-0.196	0.096
	(0.144)	(0.224)	(0.212)
Precipitation	0.000	0.000	-0.000
	(0.000)	(0.000)***	(0.000)
Country-Years	71	71	71

Notes: * .10 ** .05 *** .01 significance levels. Appendix II displays all interaction terms and controls in the 12 treatment seeking behavior options presented in Figure 2. These results were generated using Equation (1), which includes all controls, country fixed effects, and year fixed effects. Observations are children under 5 years of age reporting a fever in the last two weeks. All regressions include denormalized sample weights and the robust standard errors are in parentheses.
Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Table C3: Treatment Seeking Behavior: Participating Countries Analyzed Separately

	Children ages 0-59 months with fever		
	Took ACTs Private Sector	Took ACTs Public Sector	Took Non-ACTs Any Sector
ACTs subsidy GH*Post 2010	0.004	0.011	-0.026
	(0.038)	(0.068)	(0.092)
ACTs subsidy NG*Post 2010	0.021	0.017	-0.062
	(0.019)	(0.052)	(0.067)
ACTs subsidy UG*Post 2010	0.191	0.114	-0.187
	(0.046)***	(0.056)**	(0.068)***
Characteristics of the Head of Household			
Age in years	-0.000	-0.002	-0.001
	(0.003)	(0.005)	(0.007)
Female	-0.116	-0.142	-0.431
	(0.147)	(0.277)	(0.353)
Characteristics of the Mother/Caretaker			
Age in years	-0.010	0.029	0.031
	(0.009)	(0.021)	(0.033)
Years of education	0.006	0.028	-0.014
	(0.004)	(0.012)**	(0.020)
Characteristics of the Child			
Age in months	-0.001	-0.001	0.012
	(0.004)	(0.007)	(0.010)
Female	-0.167	-0.079	0.032
	(0.183)	(0.427)	(0.570)
Poorest	0.085	-0.204	0.757
	(0.282)	(0.453)	(0.593)
Poorer	0.370	0.804	-0.876
	(0.322)	(0.454)*	(0.620)
Richer	0.180	0.282	0.254
	(0.310)	(0.500)	(0.670)
Richest	0.150	0.071	0.117
	(0.229)	(0.333)	(0.447)
Rural	-0.033	0.036	-0.095
	(0.054)	(0.120)	(0.168)
Malaria Prevalence Factors			
Malaria endemicity	0.004	-0.079	-0.071
	(0.130)	(0.234)	(0.223)
Precipitation	0.000	0.000	-0.000
	(0.000)	(0.000)***	(0.000)
Country-Years	71	71	71

Notes: * .10 ** .05 *** .01 significance levels. Appendix II displays all interaction terms and controls in the 12 treatment seeking behavior options presented in Figure 2. These results were generated using Equation (1), which includes all controls, country fixed effects, and year fixed effects. Observations are children under 5 years of age reporting a fever in the last two weeks. All regressions include denormalized sample weights and the robust standard errors are in parentheses.
Source: Author's calculations of the Demographic and Health Survey, Malaria Indicator Survey, Multiple Indicator Cluster Survey, Malaria Atlas Project, and NASA data for years 2006-2016.

Appendix D: Description of Variables

The Demographic and Health Surveys, Malaria Indicator Surveys, and Multiple Indicator Cluster Surveys are designed for within country-year analysis. Variable names and codelists are often not consistent across countries and/or years. To address this challenge, I mapped the French and Portuguese variable responses to their corresponding English response. Next, I recoded all variables to allow for a pooled analysis. Below is a description of how some of the variables were constructed that may not be obvious to the reader. At the end, I provide a list of variables that were excluded from the analysis and an explanation for their exclusion.

9.1 Variables Included in the Analysis

9.1.1 Covariates: Characteristics of the child

Wealth index (5 indicators). The wealth index is calculated using Principal Components Analysis based on household's ownership of selected assets, such as televisions and bicycles, materials used for housing construction, fuel used for cooking, and types of water access and sanitation facilities. It is used to determine a household's relative economic status. Five indictors are generated to represent five economic status categories: poorest, poorer, middle, richer, and richest.

Rural residence (indicator). Based on country-specific definition of urban vs. rural residence.

9.1.2 Covariates: Characteristics affecting malaria prevalence

Malaria transmission intensity (continuous for regressions) This is a continuous measure for the Plasmodium falciparum parasite rate for children 2 to 10 years of age (PfPR2-10). The 2 to 10 years age group is standard practice for defining malaria transmission intensity because it has good biological, epidemiological, and statistical properties. It is the optimal age group because PfPR reaches a peak after about two years and remains fairly constant

in older children until age ten before declining throughout adolescence and adulthood (due to acquired immunity).

Following the method used by Lim, Fullman, and Stokes et al. (2011) for determining malaria transmission intensity, I use GPS coordinates for each primary sampling unit in the surveys and spatially join these points to the nearest point within 5 kilometers on the GeoTIFF maps for malaria endemicity for years 2006-2016 from the Malaria Atlas Project (http://www.map.ox.ac.uk) (Hay et al 2010) using ArcMap v10.3.1 software. For the survey-years without GPS data available, I collapse the most recent survey-year GPS PfPR2-10 data for that country to the country-region level. I merge the collapsed GPS PfPR2-10 data with the survey-years without the GPS PfPR2-10 data by country-region and year of survey.

Malaria transmission intensity (categorical). I categorize malaria transmission intensity into the following categories: (i) high transmission, defined as PfPR210 between 40%100%; (ii) medium transmission, defined as PfPR210 between 5%40%; and (iii) low transmission, defined as PfPR210 between 0%5% (Hay, Smith & Snow 2008).

Average monthly precipitation (mm/month) (continuous). Refer to Alfani et al (2015). First, I downloaded separate average monthly precipitation maps in NetCDF format for every country-year-month included in the survey from NASA (2015). Next, I spatially joined each map the nearest planar point representing the primary sampling unit (the household cluster) using the GPS coordinates from the survey data. Four countries without GPS data, I follow the same procedure described in the malaria transmission intensity variable construction.

9.2 Variables Excluded from the Analysis

Variables were excluded from the analysis if there was a significant amount of observations with missing data for that variable. These variables were excluded to avoid the regressions from dropping the entire observation due to missing data for a single variable.

9.2.1 Outcomes

Anthropometric measures These include low birthweight (¡2500 grams), height for age percentile, weight for age percentile, and weight for height percentile are not included as outcomes for this analysis on the impact of subsidized ACTs on treatment seeking behavior. These outcomes are more appropriate for assessing the impact of vector control or IPTp interventions.

9.2.2 Covariates: Characteristics of the child

Child's place of delivery Not collected for every child or every country-year.

Child's vaccination history Not collected for every child or every country-year.

Mother's iron supplementation Not collected for every child or every country-year.

9.2.3 Covariates: Characteristics affecting malaria prevalence

Vegetation Index The Normalized Difference Vegetation Index data are available from NASA. A similar procedure to that of the Average Monthly Rainfall variable is being considered for this analysis. More time is needed to construct this variable.

9.2.4 Covariates: Causal pathways

The following covariates are categorized as other malaria control interventions that a child with fever (or their household) may be participating in. They were excluded from the analysis because they are considered causal pathways. Refer to the Data section of this paper for more details for their exclusion.

Insecticide-treated bed net (ITN) ownership (indicator). ITN ownership is defined as a positive response to the survey question, "Does your household have any mosquito nets that can be used for sleeping?" More granular data on the type of mosquito net, brand of mosquito net, how long ago it was treated with insecticide, and the condition of the net were not considered since these factors are not collected for every survey.

Indoor residual spraying (IRS) (indicator). I define IRS as a positive response to the survey question, "Has the dwelling been sprayed against mosquitoes in the last 12 months?" were generated. Although WHOPES (2005a & 2005b) guidelines for indoor residual spraying indicate that only the insecticide DDT is an effective vector control method lasting longer than six months, the survey data do not collect information on the insecticide applied to the dwelling or more granular temporal data.

9.2.5 Covariates: Participation in other malaria control interventions

Child slept under an ITN last night The question for this variable was not asked in a consistent manner across surveys and years. For example, some surveys asked if any child under five years of age in the house slept under an ITN last night and other surveys asked if this child (the unit of observation) slept under an ITN last night. I am interested in the latter response. This variable was also excluded due the potential for the guardian's reporting bias.

Intermittent preventive treatment in pregnancy (IPTp). This malaria control intervention reduces maternal malaria episodes, maternal and fetal anaemia, placental parasitemia, low birth weight, and neonatal mortality. The intermittent preventive treatment in pregnancy intervention is not incorporated into the model since the outcomes will not affect children aged 1 to 59 months.

Mass screen and treat (MST). Data on this malaria control intervention are not available.

9.2.6 Covariates: Characteristics affecting access to treatment

Density of Public Sector Health Facilities The distance that a child lives to the nearest public sector outlet may affect her participation in malaria control interventions as well as purchasing subsidized ACTs in the private sector. Unfortunately, these data are not available. Alternative measures, such as distance to the nearest road are being considered.