Prices, Diagnostic Tests and the Demand for Malaria Treatment: Evidence from a Randomized Trial[1]

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Abstract

Currently fewer than 15% of children with malaria are treated with effective medicines, largely due to widespread parasite resistance and high costs of Artemisinin Combination Therapies (ACTs), the only class of antimalarials currently effective against *P. falciparum* malaria. The Affordable Medicines Facility for malaria (AMFm) is a large planned initiative to subsidize the bulk of the cost of ACTs to suppliers. A primary objective is to dramatically reduce the final price of ACTs to consumers in the retail sector (drug shops), where malaria treatment is most commonly sought. Ensuring that ACTs are affordable will also help crowd out the use of arterminisin as a monotherapy, thereby slowing artemisinin resistance. The majority of people seeking malaria treatment in drug shops have had no formal diagnosis, however, and substantial increases in access to ACTs will most likely be associated with increases in inappropriate ACT use. A high rate of overtreatment with ACTs is problematic because it wastes subsidy money and could speed the evolution of parasite resistance to ACTs. This paper reports on a field experiment from Western Kenya in which subsidized ACTs were made available in drug shops, along with subsidized Rapid Diagnostic Tests (RDTs) for malaria. We explore whether the targeting of the ACT subsidy to people with confirmed malaria could be improved by creating financial incentives for individuals to be tested prior to ACT purchase. We find that 64% of ACT takers age 9 and over (and 32% overall) actually do not have malaria. Further, over-treatment increases somewhat as the price of ACTs declines. When offered a voucher for subsidized RDTs, more than 80% of households who visit the drug shop choose to get the patient tested prior to ACT purchase. However, because the majority of people who test negative go on to purchase ACTs, RDTs only modestly improve targeting. Overall, in the absence of any information or marketing campaign on RDTs, our estimates suggest that the availability of subsidized RDTs in drug shops can increase the fraction of ACT users who are malaria-positive by 11%. We find that subsidizing RDTs can reduce wastage and be particularly cost-effective among older children and adults if adherence to test results can be improved.

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Introduction

Malaria Control Today

Malaria control efforts have been rejuvenated and transformed in the 21st century. Long-lasting insecticide treated nets have been distributed on a massive scale, contributing to reductions in malaria incidence and deaths in some countries (Otten et al. 2009). Policy-makers and donors have recently been turning their attention to malaria treatment, an aspect of malaria control that has made smaller strides.

Because immunity to malaria develops with age, children under 5 are most vulnerable to acquiring and dying from malaria. How readily these children can access effective antimalarials is thus a very important determinant of overall malaria morbidity and mortality. According to the 2009 World Malaria Report, fewer than 15% of young children with fever in malaria endemic countries were treated with effective antimalarial drugs. This crisis in access has been fueled by the spread of drug resistant malaria parasites. Past malaria control efforts relied heavily on Chloroquine (CQ) as a cheap, effective treatment. *P. falciparum* resistance to CQ emerged in the 1960s and rendered the drug ineffective by the early 1990s, contributing to a substantial rebound in malaria mortality (Trape 2001). Subsequent innovations in antimalarial medicines have been successively less able to withstand parasite resistance (D'Allessandro and Buttiens 2001).

Currently, the only effective antimalarial against the *P. falciparum* parasite (the most common and deadly of the five strains of malaria) is artemisinin, a compound derived from Chinese wormwood trees that is significantly more expensive to produce than older, synthetic forms of malaria medicine. The retail price of artemisinin-based antimalarials is roughly $5-7 in Sub-Saharan Africa (ACT Watch 2010).[2] In most populations dealing with endemic malaria this cost of treatment is unaffordable. The high cost of artemisinin in the private sector (where malaria treatment is most commonly sought), combined with poor public sector stocking of these drugs at lower prices, is commonly held responsible for less than 15% of children with malaria being treated with effective medicines.

Global Health Policy for Malaria Treatment: The AMFm

Today the global health community faces two major challenges:

1) How can effective malaria medicines be made accessible and affordable?
2) How can resistance to the only remaining effective treatment be stemmed?

[2] ACT Watch, Population Services International, Outlet Surveys (http://www.actwatch.info). The median price of Artemether Lumafantrine (the drug used in this study) in drug shops is $5.26 in Uganda, $6.03 in Benin, $4.58 in DRC, $5.36 in Nigeria and $5.36 in Zambia. In most cases, other ACTs are $1 more expensive, and all ACTs are more expensive in pharmacies than in drug shops.

An answer that has gained traction in the global health community is to heavily subsidize artemisinin-based combination therapies. Similar to "cocktails" for HIV and other diseases, combination therapies for malaria that include, but are not exclusively, artemisinin can slow the emergence of resistance.[3] It is argued that large subsidies for Artemisinin Combination Therapies (ACTs) can simultaneously increase access to effective malaria treatment and slow resistance by crowding out the production and use of artemisinin monotherapies (Laxminarayan et al. 2010). The goal is to make effective drugs available to current populations, while preserving their efficacy for future ones.[4]

The global health community has embraced this ambition in the form of the Affordable Medicines Facility for Malaria (AMFm). This facility, managed by the Global Fund to Fight AIDS, Tuberculosis and Malaria and funded by UNITAID, the Gates Foundation and others, will heavily subsidize (roughly 95%) the manufacturer price of ACTs bought by certain malaria-endemic countries.[5] These subsidies will be available only to first-line buyers (including governments, NGOs and private sector importers), with no restriction on the final price to consumers.[6] The subsidy level is thus being set high enough for ACTs to be, in expectation, priced competitively with older, less effective drugs and lower than artemisinin monotherapy.

Making highly-subsidized ACTs available on a wide scale, including through the informal retail sector, will almost certainly reduce malaria-induced mortality and morbidity. In particular, it can help get ACTs to remote, vulnerable populations who do not have access to formal health care and cannot afford expensive treatment. It will also likely help to crowd out the use of monotherapy, slowing artemisinin resistance. However, given the lack of access to cheap, reliable diagnostic tools in the retail sector, lower-priced ACTs are also likely to increase the number of non-malarial illnesses being treated with ACTs.

Malaria Diagnostics

Public health experts have expressed increasing concern about significant over-treatment of malaria (Perkins and Bell 2008; Amexo et al. 2004). A history of fever is the most common basis for a clinical diagnosis, but evidence is growing that this is often a weak

[3] Combination therapies slow resistance because in order for a resistant parasite to arise, it must develop mutations that make it resistant to *all* drugs in the combinations. When the combined drugs have differing modes of action, the probability of this event occurring is substantially lower than the probability of resistance developing to any single drug alone. World Health Organization. 2010. "Guidelines for the Treatment of Malaria."

[4] This argument is laid out in detail in the 2004 Institute of Medicine book *Saving Lives, Buying Time: Economics of Malaria Drugs in an Age of Resistance*.

[5] The actual subsidy level will vary by manufacturer and dosage. The aim is to set the subsidy such that first line buyers purchase ACTs at $.05 on average. AMFm frequently asked questions (http://www.theglobalfund.org/documents/amfm/AMFmFAQs_en.pdf).

[6] The facility itself does not put a restriction on the final price, but governments, NGOs, etc. are permitted to institute ceilings if they choose.

predictor of malaria, and symptom-based guidelines for malaria diagnosis are very limited (Chandramohan et al. 2002; Mwangi et al. 2005). In one example from Tanzania, only 46% of people receiving in-patient hospital care for "severe malaria" actually had parasites in their blood, the same rate as the general population (Reyburn et al. 2004). Due to acquired immunity, the chances that a febrile patient has parasites declines rapidly after age 5 and thus overtreatment is much more likely among older children and adults (Reyburn et al. 2004). In a Tanzania study with drug shop customers, only 18% of those 5 and over buying antimalarials were parasitemic (Kachur et al. 2006). Parasite prevalence in the area for this age group was 9%, suggesting that symptom-based self-diagnosis in this context was not much better than a random draw from the population.

While poor access to diagnostic equipment is a major reason for malaria overtreatment—especially in the retail sector—this is a concern even in contexts where such equipment is available. A Kenya study found that 80% of malaria patients over 5 were given antimalarials despite a negative blood test; several studies in Zambia found antimalarial prescriptions given to over half of patients with a negative test (Zurovac et al. 2006; Barat et al. 1999; Hamer et al. 2007). Reasons for overtreatment and poor adherence to test results likely vary widely, but research suggests that it is largely a result of social pressures and professional norms rather than, e.g., insufficient training (Chandler et al. 2008).

Some have argued that presumptive treatment of malaria may have been a wise strategy in the past, but that changing malaria epidemiology and control programs, as well as improved diagnostics, make a diagnostic-based approach now more attractive (Perkins and Bell 2008). High rates of malaria overtreatment have a number of downsides, including delaying (or precluding) proper treatment for the true cause of illness and accelerating drug resistance (Rafael et al. 2006; Perkins and Bell 2008). While ACT subsidies likely have a first order effect on resistance because of monotherapy crowd-out, there is potentially a second order negative effect accelerating resistance from overtreatment with ACTs that could be stemmed with a diagnostic-based approach. Further, a diagnostic-based approach could potentially reduce wastage of subsidy money on people without malaria and improve learning about the effectiveness of ACTs over other antimalarials.[7]

Evaluating Targeting and Testing Solutions

The foregoing discussion highlights the apparent tension between making ACTs affordable to the most vulnerable and guarding against overuse and its associated negative effects. In this paper, we report on a field experiment conducted in Western Kenya specifically designed to explore whether the dual objectives of uptake and targeting can be improved by making subsidized rapid diagnostic tests (RDTs) for malaria available in drug shops

[7] See, e.g., the model in Adhvaryu (2009) that misdiagnosis can slow learning and adoption.

along with subsidized ACTs. We ask whether bundling ACT subsidies with an RDT subsidy can create a financial incentive for individuals to learn their malaria status prior to purchase.[8]

Our field experiment varied the prices of ACTs and RDTs sold in drug shops. Since the final price to consumers after AMFm subsidies is unknown and is likely to vary substantially, we look at the impact of ACT price variation on uptake and targeting (Patouillard et al. 2010). We then ask whether uptake and targeting of subsidized ACTs in the retail sector can be improved by making subsidized RDTs available.

In the absence of diagnostics, we find that targeting at drug shops (where most households turn in case of febrile illness) is relatively poor except in the case of young children. While 82% of ACT-takers under age 5 test positive for malaria, only 53% of takers aged 5 and over test positive, and this drops to 36% for takers over age 9.

Lower ACT prices increase uptake of ACTs in drug shops, but also somewhat increase the share of ACT-takers who are malaria-negative. This appears to be largely driven by an age composition effect: when ACT prices decrease, ACT demand increases relatively more among older patients than among young children.

In the absence of any marketing or information campaign, RDTs do not appear to be an easy fix to that problem: we find that making RDTs available in the retail sector has only a modest (11%) impact on targeting of ACTs to malaria-positive users. This doesn't appear to be because people refuse to take or pay for RDTs, but rather because people tend to purchase ACTs despite a negative malaria test. While part of this could be due to hoarding (purchasing the medicine to save for later use), we also have suggestive evidence that people did not trust the negative results.

This study provides the first experimental evidence of willingness-to-pay for ACTs and RDTs and of targeting to malaria-positive people associated with various subsidy levels. Our results on overtreatment are in-line with observational studies of facility-based malaria treatment in Africa (e.g. Zurovac et al. 2006; Barat et al. 1999; Hamer et al. 2007) and show somewhat less overtreatment than the one observational study of overtreatment in drug shops (Kachur et al. 2006). Our finding that a large share of ACT buyers is willing to take an RDT is suggestive that low rates of diagnostic testing for malaria is not primarily due to patient reluctance. On the other hand, our finding that a large share of malaria-

[8] RDTs for malaria work similarly to rapid tests for HIV and do not require specialized equipment, such as a microscope, or electricity. A small sample of blood is collected through a finger prick and placed on a testing cassette. The blood sample is exposed to a buffer solution, and the presence of malaria antibodies can be determined within approximately 15 minutes.

negative people go on to purchase ACTs anyway is suggestive that patient pressure and demand could be a major source of the poor diagnostic adherence among health workers observed in previous studies.

Overall, our results suggest that ACT subsidies will likely increase uptake in the retail sector, but more research is needed to understand how effective diagnostic services can be used to improve targeting of those subsidies towards people with malaria. The use of RDTs among older children and adults has the potential to generate substantial improvements in targeting and appropriate treatment, but only if patients respect the test results.

Study Design

Sampling Frame

We conducted a randomized-controlled trial in Busia, Mumias and Samia districts in Western Kenya.[9] Malaria is endemic in this region of Kenya, with transmission occurring year-round, but with two peaks corresponding to heavy rain, in May – July and October-November. This region is rural and poor, with the majority of household heads working as subsistence farmers. Daily agricultural wages are estimated at approximately $1.5 (Dupas and Robinson 2009).

We selected four drug shops, in four rural market centers.[10] Drug shops in Kenya are similar to pharmacies, but with more stringent limits on the types of drugs they can distribute. We then sampled all households in the catchment area (within a 4km radius) of each of these four drug shops. The total number of sampled households was 2,928. We then visited each household to administer a baseline survey, at the end of which vouchers for ACTs and (when applicable) RDTs were distributed. Vouchers were only redeemable at the closest sampled drug shop. Of the 2,928 sampled households, just under 5% were not reached or refused to participate, a rate that was equal across treatment groups.

Experimental Variation

The experiment included 4 categories of ACT vouchers, and 4 categories of RDT vouchers. Each household in the sample was randomly assigned to one ACT category and one RDT category, using a computerized random number assignment algorithm. The randomization was stratified by drug shop, distance to the drug shop, and by whether a household had children or not.

[9] The study protocol was approved by the UCLA IRB, the KEMRI/Kenya National Ethical Review Committee, the Kenya Pharmacy and Poisons Board and the IPA Kenya IRB.

[10] Participating drug shops were chosen on the basis of several criteria including distance from drug shops participating in other public health interventions, shop owner qualifications, length of time the shop has been in business and the number of daily customers.

Variation in Access to ACTs

Since ACTs are priced by dose, where the appropriate dose is determined by age, the four ACT categories differed in the "price-per-pill" they entitled a household to. There were four prices per pill: the prevailing market price, Kenyan shillings (Ksh) 20.83 (this is the control group); a high subsidy price of Ksh 1.66 per pill (this corresponds to the subsidy level currently being discussed in Kenya); and two intermediate subsidized prices of Ksh 2.50 and Ksh 4.16 per pill.[11] The ACT brand that was sold to voucher holders at the participating drug shops was Coartem.[12]

The following table describes the pricing and dosing regimens in the study. [13]

	Recommended Dose and Corresponding Dose Cost for:			
	Adult (14+)	**Ages 9-13**	**Ages 4-8**	**Ages 3m-3y**
Dose / *Price Per Pill*	4 pills, twice a day for three days	3 pills, twice a day for three days	2 pills, twice a day for three days	1 pill, twice a day for three days
Ksh 20.83 (Control)	Ksh 500 ($5)	Ksh 375	Ksh 250	Ksh 125
Ksh 4.16	Ksh 100 ($1.25)	Ksh 75	Ksh 50	Ksh 25
Ksh 2.50	Ksh 60 ($.75)	Ksh 45	Ksh 30	Ksh 15
Ksh 1.66	Ksh 40 ($.50)	Ksh 30	Ksh 20	Ksh 10

Henceforth, we refer to the adult dose costs (in Ksh) to distinguish the ACT treatment groups ("500", "100", "60" and "40").

[11] At the time of the study, $1 = Ksh 78.

[12] At the time of the study, Coartem was available in the public and private sectors. Public health facilities dispensed Coartem with special packaging intended to make dosing instructions clearer. This study used the more standard private sector packaged Coartem, though we also distributed handouts with pictures and Swahili instructions on how to take Coartem when dispensing the drug. All study participants purchasing Coartem from us also received detailed verbal dosing instructions from study officers stationed at the drug shops.

[13] Ideal dosing is based on weight but manufacturers and the Kenyan Ministry of Health provide age guidelines as well, as it is not always feasible to weigh malaria patients. This study utilized the age guidelines from the Kenya Ministry of Health.

For comparative purposes, Ksh 40 and Ksh 100 roughly correspond to the retail prices for adult doses of the cheapest and most expensive non-ACT antimalarials available at the drug shops in the study. Ksh 500 is the approximate prevailing retail price for unsubsidized ACTs in the study area.[14]

Variation in Access to RDTs

For each ACT price class, a household was assigned to an RDT treatment group as well. One group ("No RDT" in Figure 1) did not receive any RDT voucher. Because the availability of the RDT voucher could influence people's treatment-seeking and purchasing decisions, it was important to have a sub-sample of households whose uptake of ACTs was unrelated to RDT availability. This "No RDT" sample is the group whose behavior is most relevant in predicting the impact of the AMFm, which currently has no planned RDT subsidy.

The other RDT treatment groups to which a household could be assigned were: "RDT Free", "RDT 15", and "RDT 15, Refund." The first and second of these treatment groups were given vouchers for, respectively, a free test and a test costing Ksh 15 ($.20) regardless of age.[15] The "RDT 15, Refund" group received vouchers allowing them to buy an RDT for Ksh 15, with a full refund given if the test was positive and they purchased an ACT.[16]

Timing of Experiment and Data Collection

The study took place from May to December 2009. Households were visited at home twice. During the first visit, a baseline survey was conducted. At the end of the survey, the respondent was given two ACT vouchers at the assigned price, and, when sampled for RDT vouchers, two RDT vouchers at the assigned price. To avoid creating perverse incentives,

[14] The Ksh 500 group was only used to compare take-up of ACTs at the subsidized and unsubsidized rates. Since we expected low take-up in this group, we did not use them to explore the impact of RDTs. During the course of study, cheaper "generic" brands of ACTs began to be stocked by some area drug shops. These were still very expensive, at approximately Ksh 400 for an adult dose.

[15] At the time of the study, WHO guidelines recommended presumptive treatment of fever as malaria for children under 5 (this recommendation was revised in the 2010 guidelines to recommend diagnosis for suspected malaria cases when available). Thus, in our study, children 5 years and under were allowed to take an RDT but were recommended to take ACTs regardless of test result. If they tested negative, their parents were informed that to be safe, they should take the ACT but they should also take the child to a health facility for further testing.

[16] To avoid giving incentives to withhold ACTs from under 5s based on test results, the Ksh 15 refund was only available to patients aged 8 and older. The "RDT Free" and "RDT 15, Refund" treatments are intended to provide maximum incentives for diagnosis prior to treatment. Consider a person who is deciding between presumptive treatment with an ACT for Ksh 40 and getting an RDT prior to purchase. There is a clear financial incentive to take the RDT if it is free since, if the test is negative, the person can save Ksh 40 and, if it is positive, they don't pay any more than they would have paid for presumptive treatment (Ksh 40). The "RDT 15, Refund" treatment explores whether strong incentives to be diagnosed can be provided even when the test is not free. So, again, a person considering presumptive treatment for Ksh 40 could either simply pay Ksh 40 or could be tested for Ksh 15. If the test is positive, he receives the money back and pays Ksh 40. If the test is negative he has paid Ksh 15 but has saved the Ksh 40 he would have spent on presumptive treatment.

vouchers did not have an expiration date on them so households had no reason to attempt to redeem them in the absence of an illness episode. [17]

At the second visit, four months later, we conducted an endline survey.[18] At the end of the survey, we informed households that we wanted to collect any remaining vouchers from them, because the program was ending and the drug shops would not be able to honor the vouchers.[19]

In addition to household surveys, we collected detailed data on the transactions that occurred at the four drug shops participating in the study. We posted two trained study officers at each drug shop. The study officers were present at the shop from 9AM to 5PM, Monday to Saturday, for a period of 4 months.[20] Each time a client would present a study voucher, a study officer would record the voucher identification number, seek consent, and then ask a series of questions to the voucher-bearer about the illness episode for which the voucher was being used (characteristics of the patient, etc.).[21] In the event the client had come to redeem an RDT voucher, one of the trained study officers performed the test.

Surprise RDT Tests

A subset of households was randomly selected for a surprise RDT at the drug shop in the event they came to redeem their ACT voucher. The purpose of this surprise test was to measure malaria positivity rates among ACT takers. The surprise RDT was announced after the ACT dose had been purchased, and only for those purchases where an RDT had not already been taken. 93% of those offered the surprise RDT consented to being tested.[22] Surprise RDT tests were performed by the trained study officers posted at the drug shop. If the patient (the person for whom the ACT voucher was redeemed) had not come to the drug shop, one of the two study officers accompanied the client back to her home in order to perform the RDT test on the patient.

[17] All households were told what Coartem was, and informed that it was the best treatment available for malaria. Only households given RDT vouchers were told what RDTs were and how they worked.

[18] 4.75% of households targeted for the baseline survey were not reached. Among households interviewed at baseline, 6.45% could not be reached at endline.

[19] As compensation, all households were given a tin of cooking fat at endline regardless of whether or not they returned the vouchers to us.

[20] Households were informed of these redemption times when given their vouchers at baseline. The redemption times were also clearly posted on the back of all ACT and RDT vouchers. If people came to redeem vouchers outside of these times they were told to come back during redemption hours.

[21] Only 7% of vouchers redeemed were for individuals not listed on baseline household rosters. While these vouchers could have been sold or given away, it could also be that they are being used for new household members who were not present at baseline.

[22] In the event the RDT test turned negative, clients were given the option to sell the ACT they had purchased back to the drug shop.

The experimental set-up and sample sizes are summarized in Figure 1. Overall, this experimental design enables us to address a number of issues:

- By looking across ACT prices within the "No RDT" group, we can answer the question: "What is the impact of lower-priced ACTs on ACT demand at drug shops?"
- By looking across ACT prices within the "No RDT" group who received a surprise test, we can answer the question: "How does ACT price change the share of people taking ACTs who are actually malaria positive?"
- By comparing take-up and positivity rates of ACT takers in the "RDT Voucher" and the "No RDT Voucher" groups, we can analyze whether RDTs can be used to improve targeting.

It is important to highlight that this study is not an impact evaluation of the AMFm in that we do not capture uptake and targeting of retail-sector ACTs with and without subsidies. In order to experimentally evaluate the impact of subsidies on ACT uptake one would need a more intensive data collection strategy (e.g. health diaries or frequent surveys) that enabled them to observe ACT uptake from all potential sources, not just drug shops. Our study is not designed to capture ACT uptake from other sources. Rather than evaluating the impact of a policy with and without ACT subsidies, we focus on an ACT subsidy policy with and without subsidized RDTs. That is, we are exploring whether RDTs can improve uptake and targeting of the ACT subsidy.

Sample Characteristics

Characteristics of our sample at baseline are presented in Table 1.[23] We were successful in interviewing the female head of household 90% of the time. The household head was on average about 39 years old, with 5.5 years of education and 4.1 dependents. Thus the average household size in our sample is just over 5. The average household in our sample lived 1.7 kilometers from the drug shop where the voucher was redeemable and owned 2.2 acres of land.

In addition to relatively low levels of education and land ownership, households in our sample are in very poor health. More than two-thirds of the households report having experienced a malaria episode in the month before baseline and 55% of the households sampled for hemoglobin testing had either the female head or youngest child aged 2-17 test positive for severe anemia.[24] While anemia can result from a number of types of illnesses, it is a morbidity measure that is highly correlated with malaria parasite levels. On the other

[23] Columns 2 and 3 in Table 1 are shown to verify that the randomization was successful at balancing baseline characteristics across ACT and RDT treatment groups.

[24] 25% of the sample was randomly chosen to receive hemoglobin testing at baseline. Severe anemia is defined as less than 7 g/dL.

hand, study households owned an average of 1.8 bed nets and in the average household 58% of household members slept under a bed net the last time they slept at home.

Observational Results: Malaria Treatment-Seeking Behavior at Baseline

Despite the fact that ACTs are the first-line antimalarial treatment in Kenya—that is, should be prescribed for most malaria cases in the public sector if in stock—only 42% of our sample had heard of ACTs at baseline.[25] Table 2 explores malaria treatment seeking in more depth. Panel A presents various measures of reported malaria incidence the month before baseline.

The second panel in Table 2 reports the channel through which episodes perceived as malaria were diagnosed at baseline. Nearly half (46%) of illness episodes perceived as "malaria" are self-diagnosed, whereas 37% are diagnosed at a hospital, health center, clinic, or public dispensary. It is important to note that even when illness episodes are diagnosed as malaria at a health facility, for the most part these are clinical diagnoses based on symptoms, rather than based on a blood test. As shown in Panel F, only 29% of households who report experiencing at least one malaria episode reported having a diagnostic test of any kind, the great majority of which were done with microscopy, rather than an RDT.

Nearly 80% of the episodes perceived as malaria are treated with an antimalarial (Panel C). Consistent with the fact that many respondents had not heard of ACTs, only 21% of self-identified malaria episodes were reported as treated with an ACT in the previous month (Panel D). Depending on how we treat respondents who did not know what type of medication they took, the total share of episodes treated with an ACT could be higher, at 29% or 43%.

Among those episodes treated with an antimalarial, the most common source is the drug shop (41%). ACTs are taken for roughly 27% of episodes treated with an antimalarial (Panel E), while sulfadoxine-pyrimethamine (SP) and amodiaquine (AQ)—two drugs with efficacy limited by parasite resistance—are taken for 36% of the episodes. As people often buy multiple medications for each illness episode and, when seeking public sector care must pay registration and examination fees, the average reported cost per episode is Ksh 131 or about $1.60. Note that the median expenditure (not shown) was substantially lower, at Ksh 60.

In sum, baseline treatment seeking behavior suggests that people in this region of Kenya:

- Have frequent episodes perceived as malaria
- Typically self-diagnose or receive a clinical diagnosis without a blood test

[25] This question asked whether they had heard of common names for ACTs, such as Coartem, Artefan or AL.

- Often buy medication from drug shops
- Take ACTs a minority of the time
- Have substantial out-of-pocket expenditures on perceived malaria episodes

Experimental Results: The Impact of Price Variation in ACTs

As noted above, the AMFm subsidy level is approximately 95%, but there is currently no mandated ceiling on final prices to consumers. Since final prices for subsidized ACTs are unknown and are likely to vary substantially across drug shops (as well as across countries), this section explores the impact of price variation on uptake and targeting. The price range we explore (Ksh 40-100 for an adult dose) is relevant from a policy perspective because Ksh 40 is roughly the price of the lowest quality antimalarial alternatives to ACTs, while Ksh 100 is roughly the price of the highest quality alternatives (and this range includes Ksh 60, the median household expenditure on perceived malaria episodes). This is also an appropriate range considering retail mark-ups of other antimalarials.[26]

ACT Take-up and Price Sensitivity

Figure 2a plots voucher redemptions for all households across ACT prices.[27] 46% of households redeem ACT vouchers at Ksh 40 per adult dose ($.50). Demand drops by only 4 percentage points when the price increases to Ksh 60. At Ksh 100 ($1.25) 36% of households redeemed an ACT voucher.[28] We thus do not find much price sensitivity within the price range of Ksh 40-100. While take-up does not drop substantially between Ksh 40 and Ksh 100, only 5% of households use the ACT voucher for Ksh 500, the prevailing retail price for ACTs. While these results suggest that uptake of ACTs in drug shops would increase substantially in response to subsidies, we cannot infer how much overall access to ACTs increases across prices, since households could be getting ACTs elsewhere, principally the public sector.[29]

[26] The expected price to importers under the AMFm is roughly $.10-.22 (Roll Back Malaria ACT Pricing Fact Sheet). Adding a roughly 20% cost for transport, taxes and fees paid by importers, and then considering a 300% retailer mark-up (Chen et al. 2008), this means we should expect a final price of roughly $.36 - $.79, or roughly Ksh 30-64.

[27] These estimates are predicted values from a linear OLS regression of a dummy variable indicating whether a household redeemed any ACT voucher on ACT price dummies, RDT price dummies, as well as controls for strata. All regressions in this paper are linear OLS regressions to improve transparency in interpreting marginal effects. None of the results are sensitive to using a probit specification. (Results available from authors.)

[28] There is no statistically significant difference in uptake at Ksh 40 and 60, while the difference between Ksh 40 and 100 is significant at the 1% level.

[29] While we don't have data on public sector availability of AL during the course of the study, this information is available for Western Kenya 7-10 months prior to our study in Kangwana et al. (2009). They find that ¼ of health facilities were stocked out of AL in all doses, and 75% were stocked out of at least one dose type. Further, 60% of facilities were stocked out of the dose for the youngest age group. This data is suggestive that public sector availability of AL (especially in clinics and dispensaries) is irregular in our area of study.

The finding that roughly 40% of households purchase subsidized ACTs when available in drug shops is consistent with the results from the "pilot subsidy" tested in Sabot et al. (2009). That study, conducted in Tanzania, tried to mimic the AMFm by offering an ACT subsidy to a selected wholesaler and observing final retail prices and uptake at drug shops. After one year, they find that 44% of drug shop customers in intervention districts purchased ACTs. They also find an average price paid of $0.58, while the average price paid in our study was roughly $0.46 (not shown). This is also similar to the median stated willingness-to-pay for ACTs ($0.41) found in Tanzania in Saulo et al. (2008). The fact that our results are quite similar despite the fact that their study: a) lasted longer, b) was not voucher-based and c) included a social marketing (packaging) and behavior change component, lends credibility to the external validity of our study.

Figure 2b shows estimates for households redeeming two vouchers. Only 21% of households redeemed two vouchers over the study period (4 months) at Ksh 40. Increasing the price to Ksh 60 and Ksh 100 reduces demand by 5 and 8 percentage points, respectively.[30]

ACT Targeting by Age, Malaria-Positivity and SES

We now turn to the impact of ACT price on targeting. An important reason why overall take-up is not highly sensitive to price is because, as ACT price class (i.e. price for an adult dose) increases, households appear to be using the vouchers for younger members. This is clearly illustrated in Figure 3, which shows the age composition of users at each ACT price class. At Ksh 40 per adult dose, roughly 43% of users are "adults" (14+ years) or "teens" (9-13) and 57% are "children" (4-8) and "infants" (3mos-3 years) (for whom the dose cost only Ksh 10). At Ksh 60 per adult dose, the composition of users shifts to 31% adult/teen and 69% infant/child and remains similar at Ksh 100 (the prices per infant dose become Ksh 15 and Ksh 25, respectively).[31]

These results imply that price sensitivity is highest for adult doses. This is not surprising, since (1) adults must pay the most for an ACT dose within a given price class and (2) illness episodes among adults are likely less severe. This latter point can be seen in Figure 4, which uses the data collected through the "surprise RDTs" to plot malaria positivity rates

[30] Figure 2b, the difference between Ksh 40 and 60 is statistically different at the 5% level, and the difference between Ksh 40 and 100 is significant at the 1% level.

[31] One might be concerned that, rather than changing the age composition of users, higher ACT price classes just cause older people to buy sub-therapeutic doses. While there is no way for us to dismiss this possibility with certainty, our data suggest that this was probably not the case. Specifically, we saw no evidence of child doses being bought for adult patients. This is subject to the caveat that households might have lied about which member was the patient (who was sick), as well as the caveat that mis-dosing could be more prevalent in a "real world" setting, where drug shop employees are responsible for allocating doses.

for ACT users at each price class, by age group. [32] Only 34% of "teens" and "adults" (ages 9 and up) for whom ACTs are bought at the lowest price class test positive for malaria. However, among "infants" and "children" (3 months – 8 years), malaria positivity among ACT users at Ksh 40 is 84%.

Overall, given this difference in malaria-positivity rates across age groups, the shift in age composition of ACT users at higher prices has implications for targeting toward malaria-positive people. This is shown in Table 3, which presents results from OLS regressions of malaria positivity on dummies for ACT price class (top panel) or a linear ACT price variable (bottom panel). Among all age groups, 56% of ACT users are malaria positive under the Ksh 40 price class, but under the Ksh 100 price class, 56+9=67 percent of users are malaria positive. This corresponds to a 16% increase in malaria positive users relative to users at the Ksh 40 price class. The coefficient on the linear price variable is .129 (significant at the 10% level), suggesting that a Ksh 100 increase in ACT price increases the share of users who are positive by 13 percentage points (a 19% increase evaluated at the dependent variable mean).

Taken together, these results suggest that higher ACT prices improve targeting somewhat, since they direct ACTs to younger people who are substantially more likely to actually have malaria. One might also expect a selection effect of ACT price on positivity if people with more severe illness are willing to pay more and those with severe illness are more likely to have malaria.[33] To study these selection issues in detail, Table 4 presents results from OLS regressions of various demographic and health characteristics on ACT price among the sample of households buying ACTs. The results show no pattern—even characteristics related to malaria such as bed net ownership and reported malaria episodes are unrelated to the act of paying a high price for ACT treatment. Other than whether or not the household treats their water, the only significant relationship between household characteristics and purchase of higher priced ACTs is the youngest child in the household's hemoglobin (measured at baseline). The coefficient on hemoglobin is negative and significant at the 10% level, suggesting that households who had sicker children at baseline are willing to pay more for an ACT. Price paid for an ACT is uncorrelated with other variables indicative of SES such as education, literacy, land ownership and household materials. Overall, the finding that SES is uncorrelated with the price paid for ACTs is consistent with Sabot et al. (2009).

Experimental Results 2: The Impact of Subsidizing RDTs

[32] All results looking at targeting by malaria status use first voucher redemptions only, as this is when the "surprise test" was administered.

[33] If poorer people are more likely to have severe illness and also less likely to be able to pay higher ACT prices, this selection effect could go in the other direction.

We now turn to the results regarding RDTs and explore whether RDTs can improve targeting of ACTs to malaria-positive people.

RDT Take-up and Price Sensitivity

Figure 5 plots the basic results on take-up of RDTs. The left panel in Figure 5 illustrates that approximately 37% of households who got an RDT voucher redeemed it at the drug shop, a rate that does not differ much across RDT price groups. Households who had to pay Ksh 15 for an RDT were not significantly less likely to get one than households who got the RDT free, conveying that households indeed have some willingness-to-pay for RDTs. The right panel in Figure 5 shows that over 80% of households who received RDT vouchers and visited a drug shop chose to redeem an RDT voucher and get tested, suggesting that there is no psychological barrier to RDT take-up (such as fear or mistrust) in this population.

Selection and Impact on ACT Targeting

There are several ways in which the availability of RDTs could influence targeting of ACTs to malaria-positive people. The two most important channels are "information" and "selection" effects. Information effects refer to the impact of learning one's malaria status on the antimalarial purchase decision. Here, we would expect individuals who learn that they are malaria negative to have a much lower willingness to pay for ACTs than individuals who learn that they are malaria positive, all else equal. Selection effects refer to the impact of making RDTs available (affordable and easily accessible at the drug shop) on who shows up to the drug shop. RDTs could encourage treatment seeking at the drug shop in two ways: 1) they could draw people who might have gone to the public sector for a diagnosis, 2) they could draw people who otherwise would not seek any treatment at all (e.g. would stay home and self-medicate with an anti-pyretic). In their study of drug shop customers in Tanzania, Kacher et al. (2006) found that only 17% of febrile customers purchased antimalarials (the rest purchased antipyretics). Thus a potential benefit of RDTs is the encouragement of treatment seeking among this "missed" group. *A priori*, it is unclear whether RDTs would induce people who are more or less likely to test positive for malaria to come to the drug shop. The net effect of RDTs on targeting will depend on both selection and information effects, which we explore in this section.

Turning first to selection effects, we find little to no evidence that RDTs increased treatment seeking at the drug shop. We explore this in Table 5, Column 1, which presents coefficient estimates from a regression of whether a household sought treatment at the drug shop on RDT treatment group dummies (Specification 1) or on a dummy variable indicating whether any RDT voucher was given (Specification 2). Specification 1 shows that only households in the "RDT 15, Refund" group were significantly more likely to visit the participating drug shop than those in the "No RDT" group, by 5.8 percentage points (14%).

When all RDT groups are pooled together (Specification 2, Column 1) RDT vouchers have no significant impact on treatment seeking.[34]

In addition to having no influence on the number of people seeking treatment at the drug shop, RDT availability had no effect on the type of people seeking treatment. The results in Table 5 (Specification 2, Column 2) show that RDT vouchers did not have a selection effect on malaria positivity of treatment seekers. That is, among households who received an RDT voucher, those who sought treatment at the drug shop were just as likely to be malaria positive as those who sought treatment in the "No RDT" treatment groups. In sum, we find no evidence of selection effects of RDTs. This implies that RDTs did not "crowd out" treatment seeking in the public sector, but nor did they induce diagnostic seeking among people who were not seeking treatment otherwise.

Figure 6 explores the information effects of RDTs. Almost everyone (98%) who tested positive went on to purchase an antimalarial with an ACT voucher. In contrast, a substantially lower (though still large) share of those who tested negative went on to purchase an antimalarial with an ACT voucher. While 60% of RDT negative patients went on to purchase an ACT overall, the share was rather variable over treatments, with much higher compliance to test results in the RDT 15 group than in the other RDT treatment groups. It should be noted that results here cannot be interpreted as the impact of learning one's malaria status on the decision to take an antimalarial (a pure information effect), however. This is because one's malaria status is not randomly assigned – those households with a malaria-positive patient might be systematically different than those households with a malaria-negative patient. Also for interpretation, it is important to note that we are exploring the impact of information provision on people who have chosen to come to the drug shop and be tested—most likely a selected sample.

The overall effect of RDTs on ACT targeting is illustrated in Figure 7, which shows the fraction of ACT users who test positive for malaria across treatment groups. Just under 70% of ACT users in the "No RDT" group test positive for malaria.[35] Positivity rates are increasing slightly with RDT price and are highest in the group with RDT vouchers for Ksh 15 at 80%. This overall effect of RDTs on targeting is illustrated in Column (3) of Table 5, which shows coefficients from a regression of a dummy variable for malaria positivity on RDT treatment group, among individuals for whom ACTs are purchased. For all age groups,

[34] We ran an OLS regression of whether a household sought treatment on ACT price dummies, RDT price dummies and their interaction, and find no significant coefficient on the interaction terms. Running the same regression with "bought an ACT" as the dependent variable also yields no significant coefficients on the interaction terms. In other words, RDTs do not seem to matter more for treatment seeking or for buying ACTs at different ACT prices. (Tables available from the authors upon request).

[35] Note that the means for the No RDT group differ between Figure 7 and Table 5. This is because the means in Figure 7 are regression-adjusted rather than raw means.

the coefficient on a dummy for "Any RDT" is .073 (significant at the 10% level), which indicates that the availability of RDTs increases the share of ACT users who have malaria by a modest 7.3 percentage points (11%).

The relatively low impact of RDTs on the share of ACT users who are malaria positive is due to two factors: first, the majority of patients (68%) who come to the drug shop for an RDT are malaria positive. Second, a substantial fraction of individuals who get a negative result still choose to purchase ACTs, even when the patient is older than 5. Understanding why negative RDT results do not discourage take-up of ACTs is an important question for future work. One possibility is that the confidence level in RDT results is low. Some suggestive evidence of this is that, while more than 32% of households who took an RDT tested negative, only around 16% reported having tested negative in the endline survey. Another possible explanation for the high ACT purchase rate after a negative RDT result is hoarding – households might have decided to buy the ACT dose and to keep it for later (the next malaria episode). Such hoarding could have been encouraged by the experimental design (if households were afraid the vouchers would expire or that the supply of ACTs at drug shops would dry up).[36]

Cost Effectiveness

We explore the cost-effectiveness of an RDT subsidy in Table 6. The metrics we use include measures of overall cost savings (such as "total subsidy per 100 patients" and "cost per dose to malaria positive patients"), measures of targeting (e.g. "share total subsidy on ACTs for malaria positive patients" and "share of ACTs taken by malaria positive patients") and measures of wastage (e.g. "share total subsidy spent on ACTs to malaria negative"). We consider three hypothetical worlds: a no-RDT subsidy regime, an RDT subsidy regime with no improvement in adherence to test results (as compared to the adherence we observed in our study), and an RDT subsidy regime in which no one who tests negative purchases an ACT (high adherence). These estimates likely significantly understate the value of RDTs in that they do not consider benefits of: 1) reduced probability of resistance, 2) improved adherence to ACTs, 3) improved learning about ACT effectiveness, 4) reduced probability of morbidity and mortality from the true cause of illness and 5) reduced burden on the public health system of malaria treatment. On the other hand, if there are significant direct and indirect costs of dealing with a negative test result (e.g. from alternative diagnoses, etc.) then these estimates could overstate the value of RDTs.[37]

[36] On the other hand, the fact that the overall redemption rate of ACT vouchers was relatively low (i.e. less than 20% of households redeemed both vouchers) suggests that hoarding behavior was limited.

[37] For example, in the cost effectiveness calculation in Shillcut et al. (2007), it is assumed that 5-15% of non-malarial fevers are caused by bacterial infections, with an average cost of $.61-.93 for antibiotics.

Panel A gives results for all age groups. We find that subsidizing RDTs is more expensive both overall and in terms of cost-per-ACT-dose than a no-RDT regime, but that RDTs do improve targeting somewhat, increasing the share of ACTs taken by malaria positive people and decreasing the share of the overall subsidy going to ACTs for malaria negative people. Improving adherence (Column 3) does improve the attractiveness of RDTs from a financial perspective somewhat, but it is still more expensive than a no-RDT regime.

It is most relevant to consider the cost-effectiveness of RDTs for older children and adults, since the great majority of young children test positive in our study. Panel B and Panel C explore whether RDTs are attractive for people over age 5 and over age 9 respectively. In both cases subsidizing RDTs without an improvement in adherence to test results is still more expensive than not subsidizing RDTs. However, we find that if adherence to test results can be improved, RDTs can be cost-neutral (for 5 and over) or cost-saving (9 and over). The share of the total subsidy going to ACTs for malaria-negative people can be reduced from 53% to 23% for over 5's, and further to 8% if adherence to test results is improved. Among ages 9 and up, the share of ACTs taken by malaria positive people can be increased from 37% to 56% without improvements in RDT result adherence, and up to 81% if RDT result adherence is improved.

In sum, RDTs appear to reduce wastage and improve targeting when subsidized and recommended for older children and adults. They can also be cost-effective in terms of total subsidy spent, particularly if adherence to test results improves. This is consistent with the analysis in Lubell et al. (2008), which uses data from Tanzania hospital patients with suspected malaria to illustrate that RDTs are only cost-effective when clinicians respect the test results. It should also be noted that, holding RDT take-up and adherence behavior constant, RDTs would be substantially more cost-effective in regions with more moderate or low malaria endemicity. This is consistent with the analysis in Shillcut et al. (2007), which shows that RDTs are not cost-effective relative to presumptive treatment at very high levels of malaria prevalence (above 90%) but are very cost-effectiveness and moderate and low prevalence levels (below 62%). Understanding behavioral responses to RDTs across endemicity settings is an important area for future research.

Conclusion and Discussion

The standard first response to perceived malaria episodes among households in our study seems to be to self-diagnose and purchase over-the-counter medication in a drug shop, bypassing the formal health care system altogether. We find that a substantial fraction of these drug shop customers do not have malaria: our field experiment revealed that only 37% of people over age 9 for whom subsidized ACTs are purchased test positive for malaria. These results suggest that, if the AMFm subsidies are successful at shifting malaria

treatment to ACTs, it will most likely lead to a high rate of inappropriate use of ACTs. Further, we find that lower priced ACTs increase uptake, but reduce the fraction of ACT users who test positive for malaria, suggesting that the AMFm policy faces an access vs. targeting tradeoff.

In this paper, we have tested whether making RDTs easily accessible and affordable in drug shops can mitigate this effect. We find that RDTs are not unpopular (about 80% of people visiting the drug shop are willing to take a test when they arrive at the shop if it's offered for free or at a small fee), but they are not yet a very effective means for reducing over-treatment. The majority of individuals in our sample went on to purchase an ACT dose, no matter what their RDT test result was. This suggests that any efforts to improve targeting through increasing adherence to test results must not only focus on provider behavior, as patients apparently choose to ignore results in the absence of provider pressure.

Understanding how to improve the impact of RDT diagnostics on households' antimalarial purchase decisions is a key next step in understanding how to ensure ACT subsidies are not wasted and do not fuel mistreatment.

Limitations

There are several important caveats to highlight with regard to interpretation of our results. First, the study was conducted in an area of very high malaria endemicity and low socioeconomic status. Behavioral responses to ACT prices and RDT prices and test results could vary substantially across endemicity settings and in a more urban context, for example. The study was also conducted over a four month time period and thus does not capture longer-term learning and adaptation to ACT and RDT subsidies. Finally, there are a number of open questions related to the feasibility of implementing a retail sector RDT subsidy, such as supplier incentives and operational/supply chain issues that this study did not address, as we focused on the demand response of consumers to such a subsidy.

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Figure 1. Experimental Design and Sample Size

		ACT Treatment Group				
		ACT 40	ACT 60	ACT 100	ACT 500 (Control)	*Totals*
RDT Treatment Group	RDT Free	169	177	173	0	519
	RDT 15, Refund	0	239	233	0	472
	RDT 15	242	237	241	0	720
	No RDT	343	342	343	189	1217
	Totals	754	995	990	189	2928

Notes: Each household received two ACT vouchers and (when applicable) two RDT vouchers. Within each cell, a random subset of households were sampled for a surprise RDT at the end of their drug shop visit, if they ever came to redeem an ACT voucher. Those who had redeemed an RDT voucher on that same visit (prior to redeeming their ACT voucher) were not re-tested.

Figure 2. Demand Curve for ACTs

Figure 2a. Fraction of Households that Redeemed at lest one ACT Voucher, per ACT price class

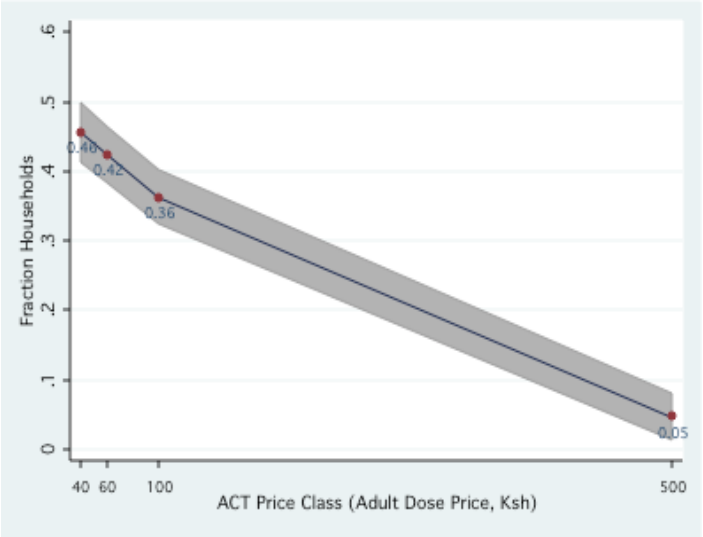
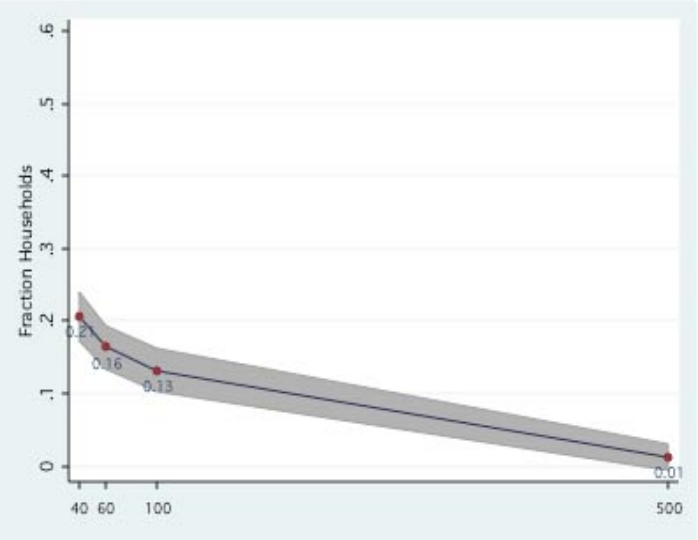
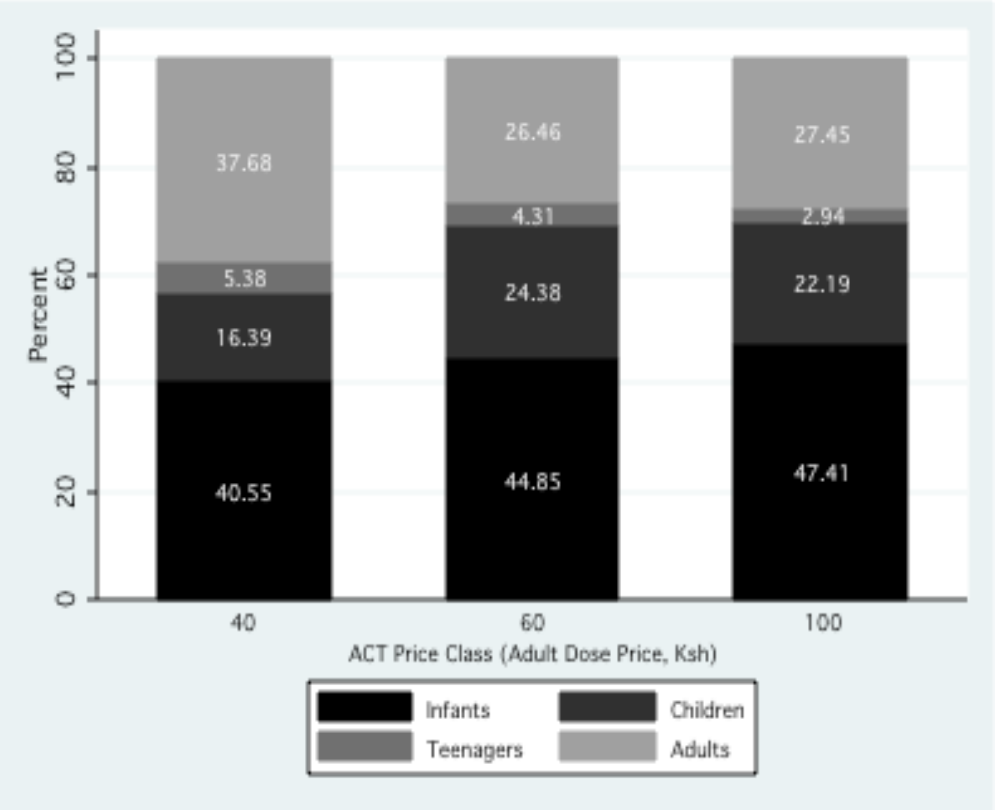


Figure 2a. Fraction of Households that Redeemed at lest one ACT Voucher, per ACT price class



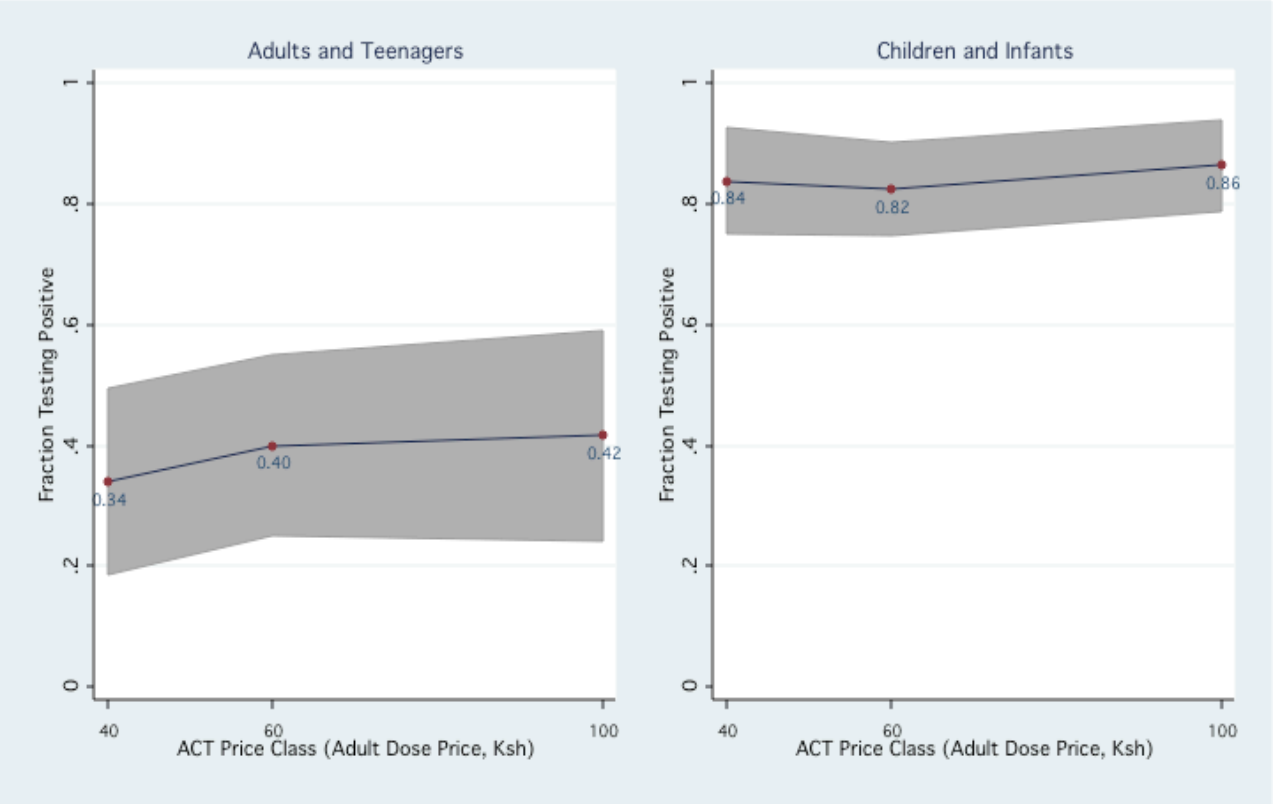
Notes: The price class corresponds to the cost of an adult dose. The corresponding prices for infant doses are Ksh 10, 15, 25, and 125 respectively. The four age groups correspond to the four dose groups recommended by the Ministry of Health. Infants are 3 months to 3 years, children are 4-8 years, teenagers are 9-13 years, and adults are 14 years and above. Grey shaded area represents a 95 percent confidence interval for estimates.

Figure 3. Impact of ACT Price on Age Composition of Patients for whom ACTs are purchased



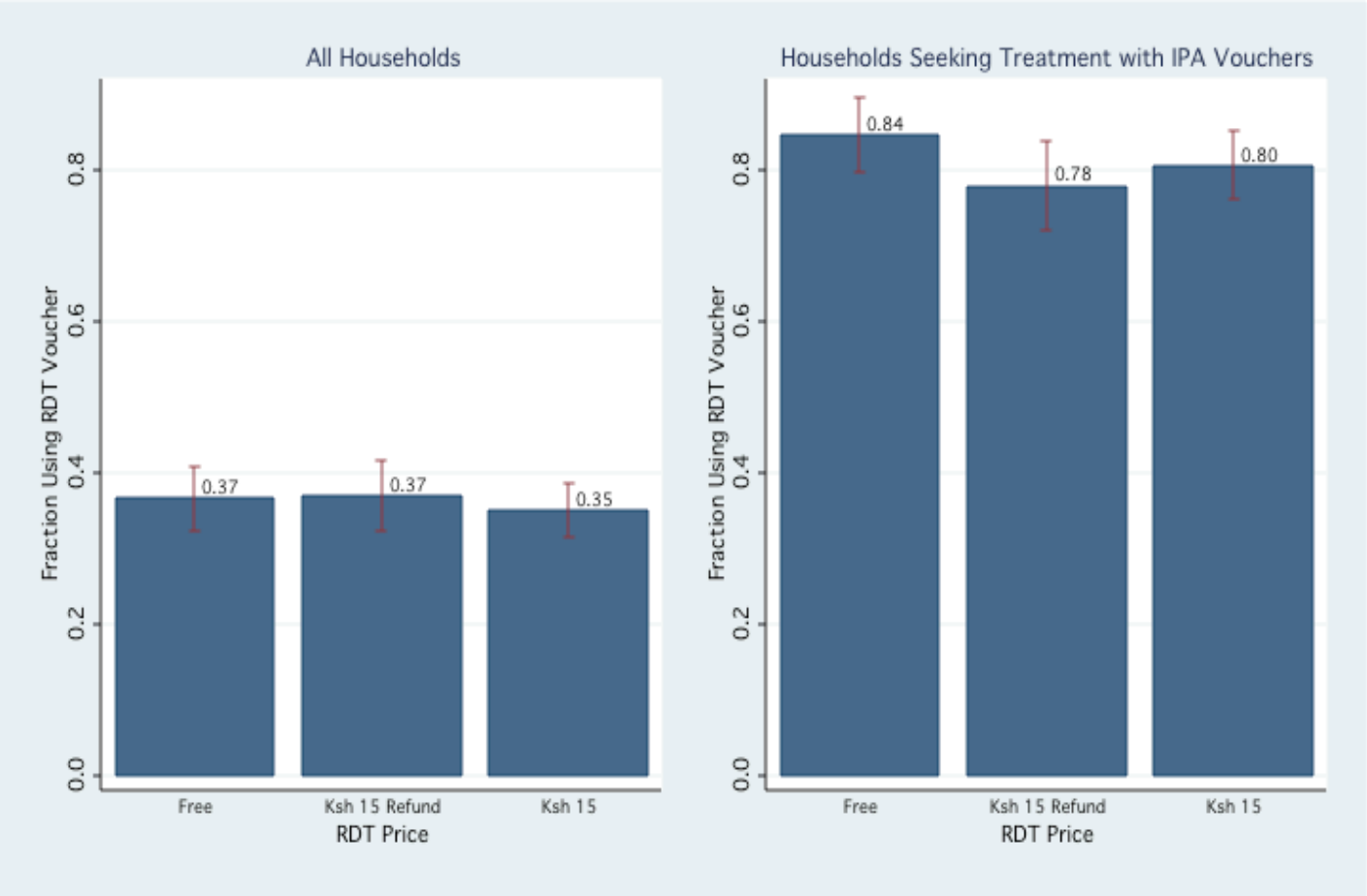
Notes: The price class corresponds to the cost of an adult dose. The corresponding prices for infant doses are Ksh 10, 15, and 25 respectively. The four age groups correspond to the four dose groups recommended by the Ministry of Health. Infants are 3 months to 3 years, children are 4-8 years, teenagers are 9-13 years, and adults are 14 years and above.

Figure 4. Positivity Rates among Patients for whom ACTs are puchased, by Age Group and ACT Price Class



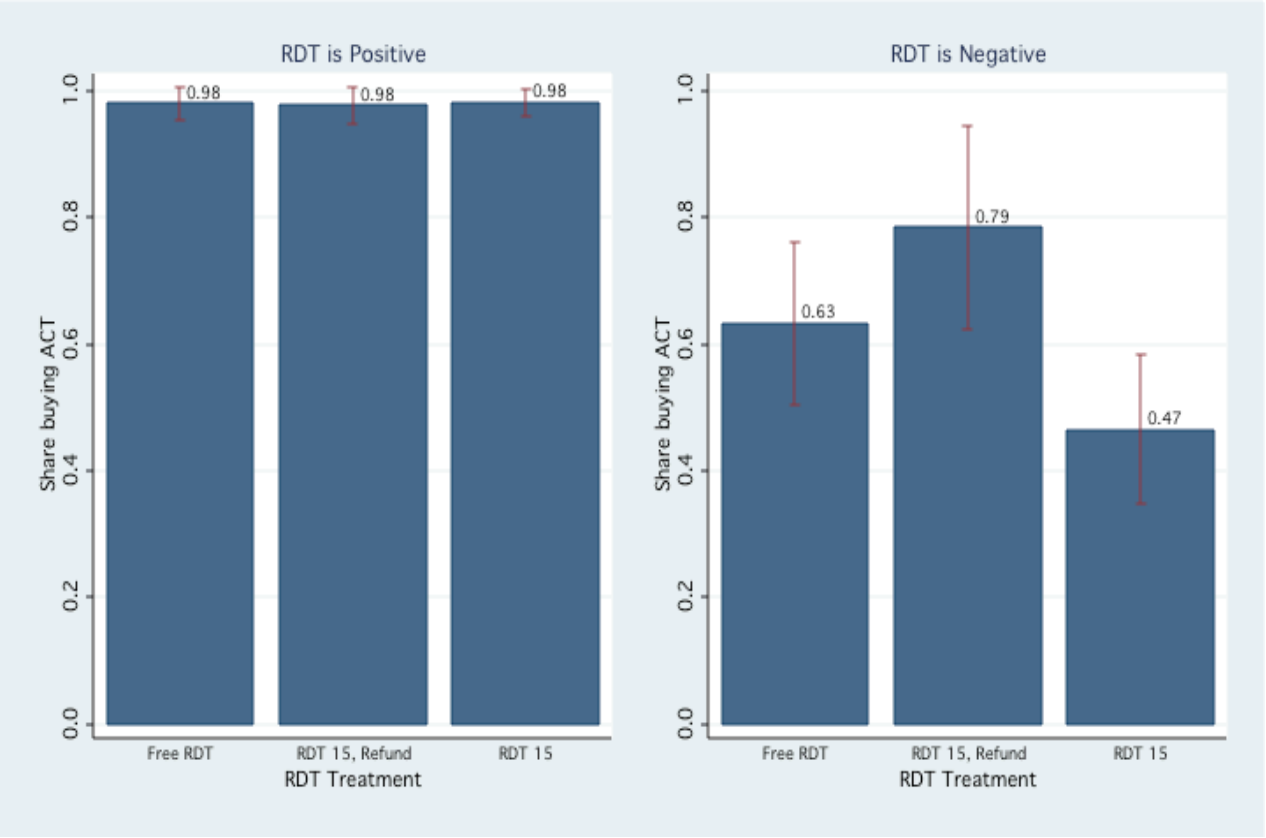
Notes: The price class corresponds to the cost of an adult dose. The corresponding prices for infant doses are Ksh 10, 15, and 25 respectively. The four age groups correspond to the four dose groups recommended by the Ministry of Health. Infants are 3 months to 3 years, children are 4-8 years, teenagers are 9-13 years, and adults are 14 years and above. Grey shaded area represents a 95 percent confidence interval for estimates.

Figure 5. RDT Take-up



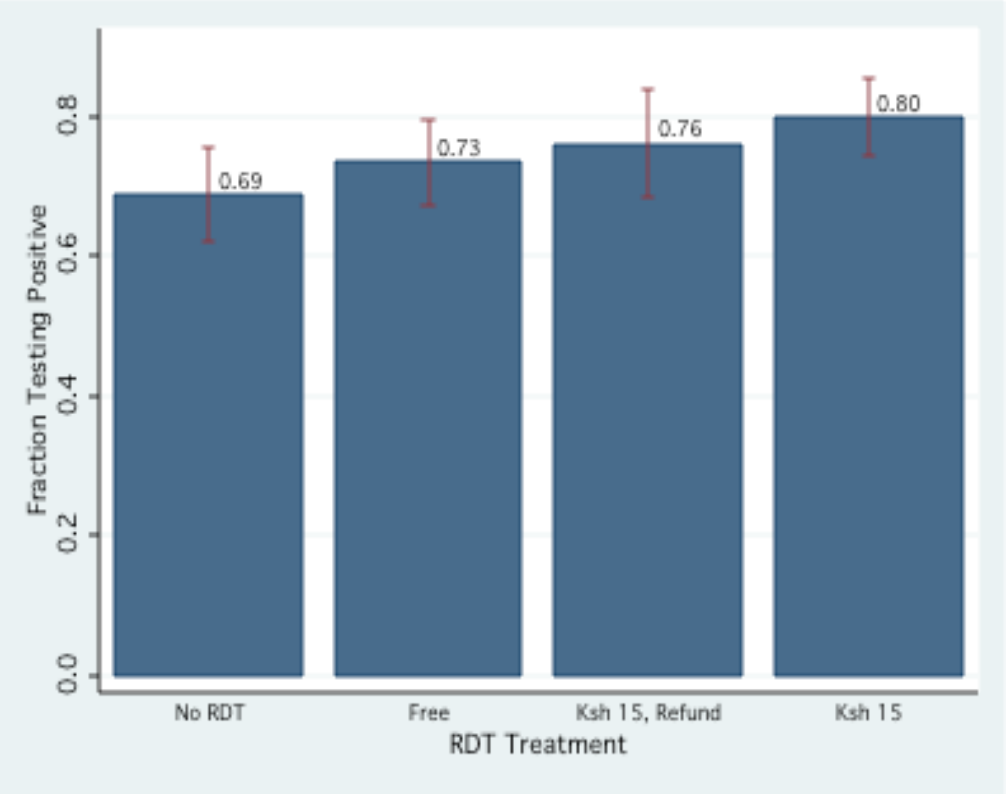
Notes: Red bars indicate 95 percent confidence intervals for estimates.

Figure 6. Information Effects of RDTs (subject to selection effects)



Notes: Red bars indicate 95 percent confidence intervals for estimates.

Figure 7. Impact of RDT availability on Targeting



Notes: Red bars indicate 95 percent confidence intervals for estimates.

Table 1. Demographic/Health Characteristics and Randomization Verification

	Mean	F-Statistic {p-value} (ACT Treatment)	F-Statistic {p-value} (RDT Treatment)	N
	(1)	(2)	(3)	
Characteristics of Interviewed Household Head				
Female	0.900	1.390	1.432	2789
	[0.300]	{0.244}	{0.239}	
Age (years)	39.034	2.116	1.714	2649
	[15.695]	{0.096}	{0.180}	
Education (years)	5.451	0.974	4.053	2774
	[4.009]	{0.404}	{0.017}	
Literate	0.618	0.741	3.655	2782
	[0.486]	{0.527}	{0.026}	
Married	0.782	0.986	2.654	2784
	[0.413]	{0.398}	{0.071}	
Number dependents	4.106	1.144	0.144	2663
	[2.543]	{0.330}	{0.866}	
Household Characteristics				
Number members	5.330	1.242	0.432	2789
	[2.488]	{0.293}	{0.649}	
Acres Land	2.232	1.354	1.983	2250
	[2.971]	{0.255}	{0.138}	
Distance from drug shop (km)	1.670	0.284	2.525	2788
	[0.904]	{0.837}	{0.080}	
Baseline Malaria Knowledge and Health Practices				
Number bednets	1.778	0.707	1.530	2784
	[1.428]	{0.548}	{0.217}	
Share HH Members Slept Under Net	0.577	0.666	1.327	2661
	[0.404]	{0.573}	{0.266}	
Heard of Coartem	0.424	0.250	0.924	2771
	[0.494]	{0.861}	{0.397}	
Heard of RDTs	0.144	0.636	0.986	2786
	[0.351]	{0.592}	{0.373}	
Malaria episode last month	0.685	1.032	0.883	2789
	[0.465]	{0.377}	{0.414}	
Treats Water Regularly	0.406	1.035	0.213	2779
	[0.491]	{0.376}	{0.808}	
Hemoglobin Testing				
Hb of Mother	8.536	1.875	1.011	580
	[3.379]	{0.133}	{0.365}	
Hb of Child	5.522	1.552	0.112	341
	[1.582]	{0.201}	{0.894}	
Any with Severe Anemia	0.544	1.587	1.807	599
	[0.498]	{0.191}	{0.165}	
Any with Moderate Anemia	0.601	2.709	1.045	599
	[0.490]	{0.044}	{0.352}	

Notes: Characteristics of sample at baseline survey. F-statistics and p-values come from regressions of demographic characteristics on ACT treatment dummies (ACT 40, 60, and 100), RDT treatment dummies (RDT free, RDT 15, RDT 15 plus refund) and strata dummies. The second column presents the F-statistic and associated p-value for a test that all ACT dummies are jointly equal to 0. The Third column presents the same test for all the RDT dummies. Standard deviations in brackets. P-values for F tests in braces.

Table 2. Treatment Seeking Behavior at Baseline Survey

	Household Level	Episode Level
A. Overall Incidence (Past Month)		
Illness Episodes/HH Member	.429	
	[.297]	
Episodes labeled as Malaria/HH Member	.246	
	[.256]	
At Least One HH Member reported having Malaria	.685	
	[.465]	
At Least One Adult/Teen Malaria Episode Reported	.408	
	[.491]	
At Least One Child/Infant Malaria Episode 'Reported	.466	
	[.499]	
B. Diagnosis Channel (Among Those Reporting a Malaria Episode)		
Hospital/Health Center	.268	.216
	[.443]	[.411]
Clinic/Dispensary	.198	.150
	[.398]	[.357]
Drug Shop	.176	.148
	[.381]	[.355]
Self	.514	.459
	[.500]	[.498]
C. Source of Antimalarials (Among Those Reporting a Malaria Episode)		
No Antimalarial Taken	.292	.221
	[.455]	[.415]
Hospital/Health Center	.296	.195
	[.456]	[.396]
Clinic/Dispensary	.245	.150
	[.430]	[.357]
Drug Shop	.558	.407
	[.497]	[.491]
Other or Forgot Name	.041	.026
	[.199]	[.159]
D. ACT Use (Among Those Reporting a Malaria Episode)		
Any Episode Treated with ACT	.251	.213
	[.434]	[.409]
Any Episode Treated with ACT - UB1*	.497	.430
	[.500]	[.495]
Any Episode Treated with ACT - UB2*	.364	.292
	[.481]	[.455]

Continued next page

Table 2 (continued). Treatment Seeking Behavior at Baseline Survey

	Household Level	Episode Level
E. Type of Medication Taken (Among Those Taking Antimalarials)		
ACT	.307	.273
	[.461]	[.446]
Sulfadoxine-Pyrimethamine (SP)	.157	.128
	[.364]	[.334]
Amodiaquine (AQ)	.272	.231
	[.445]	[.422]
Other	.198	.092
	[.399]	[.289]
Forgot Name	.264	.278
	[.681]	[.448]
E. Testing (Among Those Reported a Malaria Episode)		
Took microscopy test	.251	
	[.434]	
Took RDT	.040	
	[.196]	
Cost Per Episode (Among Those Taking Antimalarials)		
Total Antimalarial Cost (Ksh)	127	131
	[236]	[299]

Notes: Standard deviations reported in square brackets. *UB1 indicates "upper bound 1". This estimate assumes that all households who treated an illness with an antimalarial with a name that they cannot remember actually used an ACT. UB2 indicates "upper bound 2". This estimate assumes that among households who treated an illness with an unknown antimalarial, the share treating with an ACT was equal to the share treating with an ACT among households who remembered the antimalarial for all malaria episodes. $1 = approximately 80Ksh

Table 3. Malaria Positivity by ACT Price and Age Among First Voucher Redemptions

	Dependent Variable (DV) is: Tested Positive for Malaria		
	All	Adults/Teens	Children/Infants
Specification 1: ACT Price Dummies (Ksh 40 Omitted)			
ACT 60	0.069	0.055	-0.013
	(0.042)	(0.085)	(0.045)
ACT 100	0.089**	0.071	0.024
	(0.045)	(0.091)	(0.046)
Mean DV for (Ksh 40 ACT, No RDT) group	0.563	0.233	0.805
Specification 2: Linear ACT Price			
ACT Price	.129*	0.108	0.054
	(0.071)	(0.150)	(0.070)
Mean DV for (No RDT) group	0.679	0.365	0.835
N	686	221	465

Notes: Robust standard errors in parentheses. Sample is limited to first ACT voucher redemptions among households who were selected for ex-post testing. Regressions include dummy variables for strata and RDT treatment group, redemption window, and dummies for 14-day interview intervals.

Table 4. Relationship between Demographic Characteristics of ACT Voucher Redeemers and ACT Price

	Coefficient on ACT Price	F-test (Equality across ACT Prices)	N
Head education	-0.420	1.032	1049
	(.503)	(.357)	
Head Literate	-0.023	0.317	1051
	(.060)	(.728)	
Mother's Hb	1.229	0.845	232
	(.946)	(.431)	
Child's Hb	-0.843*	1.581	152
	(.499)	(.210)	
Head/spouse has phone	0.019	0.792	1051
	(.065)	(.453)	
Acres land	-0.059	0.291	852
	(.358)	(.747)	
Permanent Roof	-0.048	0.509	965
	(.068)	(.601)	
Cement Floor	0.077	0.764	680
	(.066)	(.466)	
Bednets/HH member	0.026	0.781	1049
	(.043)	(.458)	
Had Malaria Episode Last Month	-0.015	0.559	1051
	(.051)	(.572)	
Treats Water Regularly	0.128**	3.459	1047
	(0.064)	{0.032}	
Distance to chemist	-0.006	0.041	1051
	(0.022)	{0.960}	
Heard of Coartem	0.066	1.099	1045
	(0.064)	{0.334}	

Notes: Robust standard errors in parentheses. P-values in braces. The first column presents the result of a regression of ACT price on the outcome of interest (coefficients and standard errors are mulitplied by 100 for readability). The second column reports an F test on whether all the coefficients in a regression of demographic characteristics on ACT price dummies are the same. Sample includes ACT voucher redeemers at all drug shops. All regressions include controls for strata and RDT treatment group.

Table 5. RDTs and Selection to the Chemist

	Dependent Variable is:		
	Sought Treatment	Tested Positive for Malaria	
	A. Unconditional	B. Conditional on Seeking Treatment	C. Conditional on Purchasing ACT
	(1)	(2)	(3)
Specification 1: RDT Treatment Dummies (Omitted=No RDT)			
Free RDT	0.023	-0.028	0.042
	(0.027)	(0.047)	(0.047)
RDT 15, Refund	0.058**	0.055	0.067
	(0.028)	(0.052)	(0.052)
RDT 15	0.024	0.011	0.109**
	(0.024)	(0.046)	(0.045)
Mean DV for Omitted	0.415	0.675	0.679
Specification 2: RDT Treatment Pooled (Omitted=No RDT)			
Any RDT	0.032	0.006	0.073*
	(0.020)	(0.039)	(0.039)
Mean DV for Omitted	0.415	0.675	0.679
N	2608	754	686

Notes: Robust standard errors in parentheses. Sample includes all households with ACT voucher Ksh 40-100. All regressions include controls for strata and ACT price dummies, a control for redemption window (in days), and 14 day interview date dummies. Column one includes all households meeting the above criteria. Column two limits the sample to those households who sought treatment. Column three limits the sample to all households who sought treatments and were randomly selected for ex-post testing. Column four limits the sample to all households who purchased an ACT on their first trip to the shop and were selected for ex-post testing. Sought treatment is defined to refer to using an ACT or RDT voucher at the shop.

Table 6. Cost Efficiency Estimates

	No RDT Regime	RDT Regime	High Adherence RDT
	(1)	(2)	(3)
All Ages			
Total Subsidy/100 Patients (USD)	68.9	110	96.7
Cost Per ACT Dose to Malaria+ Patient (USD)	1.02	1.59	1.40
Share Total Subsidy on ACTs to Malaria+	0.566	0.383	0.435
Share Total Subsidy on ACTs to Malaria-	0.434	0.163	0.049
Share ACTs Taken by Malaria+ Patients	0.677	0.769	0.939
Ages 5 and Over			
Total Subsidy/100 Patients (USD)	103	130	109
Cost Per ACT Dose to Malaria+ Patient (USD)	1.98	2.38	1.98
Share Total Subsidy on ACTs to Malaria+	0.469	0.391	0.468
Share Total Subsidy on ACTs to Malaria-	0.531	0.230	0.078
Share ACTs Taken by Malaria+ Patients	0.526	0.667	0.881
Ages 9 and Over			
Total Subsidy/100 Patients (USD)	119	136	109
Cost Per ACT Dose to Malaria+ Patient (USD)	3.32	3.16	2.53
Share Total Subsidy on ACTs to Malaria+	0.365	0.358	0.447
Share Total Subsidy on ACTs to Malaria-	0.635	0.285	0.107
Share ACTs Taken by Malaria+ Patients	0.365	0.557	0.807

Notes: All calculations assume subsidy costs of: $0.60 per RDT, $0.055 per ACT pill. "High Adherence Regime" takes RDT takeup behavior as observed in the study, but assumes that 0% of RDT negative patients purchase an ACT.